RESULTS OF THE SUMMER 2002 MONITORING SURVEYS OF THE 1993 DIOXIN CAPPING PROJECT MOUND AT THE HISTORIC AREA REMEDIATION SITE

FINAL REPORT

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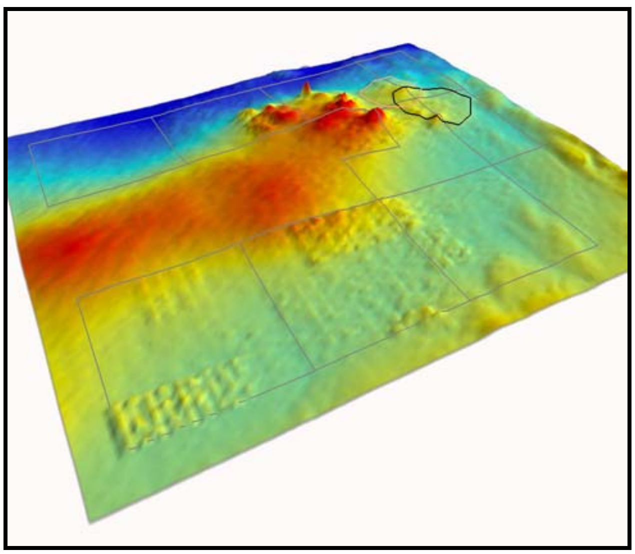

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ACKNOWLEDGMENTS

This report presents the results of the Summer 2002 Survey of the 1993 Dioxin Capping Project at the Historic Area Remediation Site (HARS). This survey was conducted by Science Applications International Corporation (SAIC) of Newport, RI, under contract to U.S. Army Corps of Engineers—New York District (NYD). Dr. Stephen Knowles is the NYD's manager of technical activities; Mr. Raymond Valente is SAIC's program manager. Dr. Knowles provided logistical and planning support for the survey, with assistance from Mr. Tim LaFontaine of the NYD's Caven Point facility.

REMOTS sediment-profile imaging, benthic sampling and coring operations were conducted aboard the NYD's M/V *Gelberman*. Single-beam bathymetry, side-scan sonar and sub-bottom profiling survey operations were conducted aboard the M/V *Beavertail*, of Jamestown, RI. The crews of the M/V *Gelberman* and M/V *Beavertail* are commended for their skill in vessel handling while conducting all survey operations, as well as their dedication during long hours of operation at the HARS.

The following SAIC staff participated in the field operations: Ben Allen, Brian Andrews, Pamela Luey, Kate Montgomery, John Morris, Natasha Pinckard, Kurt Rosenberger, Karen Shufeldt, Greg Tufts, Raymond Valente, Tom Waddington and Pamela Walter. Ocean Surveys, Inc. of Old Lyme, CT, under subcontract to SAIC, was responsible for providing vibracoring equipment and an experienced coring technician, Mr. Steve Godomski. Brian Andrews and Christine Seidel of SAIC were responsible for data tracking and management.

Applied Marine Science of League City, Texas, was responsible for the geotechnical analyses of both the sediment grab and core samples. Pace Analytical Services, Inc. of St. Paul, MN, (formerly Maxim Technologies, Inc.) conducted the chemical analyses of sediment core samples. Barry A. Vittor and Associates, Inc. (BVA) of Mobile, Alabama conducted the taxonomic analysis of the benthic grab samples.

Pamela Walter and Ray Valente prepared this report in conjunction with Brian Andrews, Natasha Pinckard, Karen Shufeldt, and Tom Waddington. Michelle San Antonio and Megan Thomas were responsible for report production.

EXECUTIVE SUMMARY

In 1993, approximately 585,500 cubic yards of sediment containing low levels of dioxin and furan were dredged from Newark Bay and placed on the seafloor in the southern portion of the former Mud Dump Site in the New York Bight. The dredged material deposit was subsequently covered (capped) with approximately 1.7 million cubic yards of clean sand; the capping operation was completed in February 1994. In accordance with a comprehensive Monitoring and Management Plan developed jointly by the New York District of the U.S. Army Corps of Engineers and Region II of the U.S. Environmental Protection Agency, numerous monitoring surveys have been conducted prior to, during, and following both the dredged material and sand capping phases of the 1993 Dioxin Capping Project.

This report presents the results of several monitoring surveys completed during summer 2002 to evaluate the long-term stability of the sand cap and its continued effectiveness at isolating the dioxin and furan contaminants known to be present in the underlying dredged material. The summer 2002 field effort represents the latest in a long-term series of postcap surveys that have been undertaken at regular intervals since the original completion of the capping operation in February 1994. The 2002 surveys included the following monitoring techniques: precision bathymetry, sub-bottom profiling, side-scan sonar, sediment vibracoring, REMOTS sediment-profile imaging, sediment plan-view photography, and grab sampling for benthic community analysis.

The results of the summer 2002 precision bathymetric survey conducted over the 1993 Dioxin Capping Project Mound were compared to the results of the previous bathymetric survey of October 1996. Where the 1993 Dioxin Capping Project Mound overlaps with the 1997 Category II Capping Project Mound, depths were found to be about 2 m shallower in 2002, due to the placement of sand in this area during the latter half of 1997 and early 1998 as part of the 1997 Category II Capping Project.

Outside the area of overlap with the 1997 Category II Project Mound, there were no significant depth changes detected over the 1993 Dioxin Capping Project Mound between the October 1996 and summer 2002 bathymetric surveys. This is the same result that has been observed in previous depth difference comparisons performed between successive postcap bathymetric surveys, indicating no appreciable change in the distribution or thickness of the sand cap since its creation in 1994.

The results of summer 2002 sub-bottom acoustic profiling survey were consistent with the bathymetric depth differencing results, indicating an average sand cap thickness of 5 to 7 feet, with the greatest thickness (up to 9 feet) observed in the area of overlap between the 1993 and 1997 mounds. Sediment cores obtained in August 2002 revealed an average cap thickness of 1.5 m (4.9 ft) over the 1993 Dioxin Capping Project Mound. Cap thickness was variable among cores, ranging from 50 cm to greater than 276 cm. These results are consistent with previous postcap coring surveys and reflect small-scale spatial variability in cap thickness. Cap thickness measurements from the summer 2002 cores were generally comparable to the cap thickness estimates obtained through sub-bottom profiling.

EXECUTIVE SUMMARY (CONTINUED)

The spatial distribution of clean, rippled cap sand detected at the 2002 REMOTS sediment-profile imaging stations was similar to that observed in several previous postcap REMOTS surveys over the 1993 Dioxin Capping Project Mound. Overall, the combined results of the summer 2002 bathymetric, sub-bottom profiling, coring and REMOTS surveys support the conclusion that the sand cap has remained stable since its creation in 1994.

Negligible (i.e., less than the 1 part per trillion) concentrations of dioxin and furan were measured in samples of the sand cap taken at various intervals in the cores. Detectable levels of dioxin and furan in samples of the underlying dredged material ranged from 1 to 100 parts per trillion. These results are consistent with those of four previous postcap coring surveys and indicate a lack of any significant vertical migration of dioxin or furan from the underlying dredged material into the overlying cap material. These results support the conclusion that the sand cap continues to remain effective in isolating the dioxin and furan from the surrounding water and sediment environment.

The 2002 REMOTS sediment-profile imaging and sediment plan-view photography results indicated that the surface of the sand cap continued to be inhabited by a benthic community comprised of small, surface-dwelling opportunists (Stages I and II), similar to the community at the nearby South Reference Area. In the area of the HARS immediately surrounding the capped mound, where fine-grained historic dredged material occurs, the benthic community consisted of a mixture of surface-dwellers (Stage I) and deeper-dwelling deposit-feeders (Stage III).

Benthic grab samples showed that several Stage I polychaetes and Stage II amphipods were among the most abundant organisms inhabiting the surface sediments at both the 1993 Dioxin Capping Project mound and the South Reference Area. The Stage II bivalve *Nucula proxima* also was found in relatively high numbers at the stations over the capped mound. The benthic grab sampling results were generally consistent with the REMOTS results in showing that the 1993 Dioxin Mound and South Reference Area were both inhabited by relatively abundant and diverse benthic communities at the time of the summer 2002 surveys. Among-station differences in benthic community composition were due to differences in sediment grain size and organic carbon content.

Both the REMOTS and benthic grab sampling results indicated that the surface of the 1993 Dioxin Capping Project mound represented a relatively healthy and productive benthic habitat at the time of the summer 2002 survey.

LIST OF ACRONYMS

2,3,7,8–TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin (Dioxin)
2,3,7,8–TCDF	2,3,7,8-tetrachlorodibenzo-p-furan (Furan)
ANOSIM	analysis of similarities
ANOVA	analysis of variance
aRPD	apparent Redox Potential Discontinuity
ASTM	American Society for Testing and Materials
BVA	Barry A. Vittor and Associates, Inc.
CH_4	Methane
CO_2	Carbon dioxide
CSV	comma delimited
CTD	conductivity-temperature-depth
CV	Coefficient of Variation (%)
DAMOS	Disposal Area Monitoring System
DGPS	Differentially-corrected Global Positioning System
DM	Dredged Material
DIVERSE	program within PRIMER
Eh	electro-chemical potential
EPA	Environmental Protection Agency
ft/sec	feet per second
GIS	Geographic Information System
GPS	Global Positioning System
HARS	Historic Area Remediation Site
HRGC	high resolution gas chromatography
HRMS	high resolution mass spectrometry
kHz	kilohertz
LOD	limit of detection
LPIL	lowest practicable identification level
m^2	square meters
M&MP	Management and Monitoring Plan
MDS	Mud Dump Site
MLLW	Mean Lower Low Water
mm	millimeter
m/sec	meters per second
M/V	Merchant Vessel
NAD 83	North American Datum of 1983
ng/kg	nanograms per kilogram
nMDS	non-metric Multi-dimensional scaling
NOAA	National Oceanic and Atmospheric Administration
NYD	U.S. Army Corps of Engineers, New York District
OLLD	Ocean and Lake Levels Division
OSI	Organism-Sediment Index
PA	Pennsylvania
PARCC	precision, accuracy, representativeness, comparability and completeness
PCDDs	polychlorinated dibenzo-p-dioxins

LIST OF ACRONYMS (CONTINUED)

PCDFs	polychlorinated dibenzo-p-furans
ppt	parts per thousand
pptr	parts per trillion
PRIMER	Plymouth Routines in Multivariate Ecological Research
QA/QC	quality assurance/quality control
QC	Quality Control
REMOTS	Remote Ecological Monitoring of the Seafloor
RPD	relative percent difference
USACE	U.S. Army Corps of Engineers
SADMA	Similar-Aged Dredged Material
SAIC	Science Applications International Corporation
SIMPER	program within PRIMER
SMMP	Site Management and Monitoring Plan
SPI	Sediment-profile imaging
TCDD-EQ	TCDD Equivalent (Dioxin Equivalent)
TEC	Toxic Equivalent Concentration
TEF	Toxicity Equivalent Factor
TEQ	Toxic Equivalent Quotient
TIFF	Tagged Image File Format
TOC	Total Organic Carbon
TVG	time varied gain
UTC	Universal Time Coordinate
yd^3	cubic yards

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1.0 INTRODUCTION

Sediments dredged from New York Harbor were deposited at the Mud Dump Site (MDS), located in the New York Bight about six nautical miles east of Sandy Hook, New Jersey, until September 1997. Based on an agreement among the Environmental Protection Agency (EPA), the Department of the Army, and the Department of Transportation, the MDS and some surrounding historical dredged material disposal areas were re-designated as the Historic Area Remediation Site (HARS; Figure 1.1-1) beginning in September 1997.

The EPA Region II and the U.S. Army Corps of Engineers (USACE) New York District (NYD) are jointly responsible for managing the HARS, primarily in an effort to reduce the elevated contamination and toxicity of surface sediments to acceptable levels. The two agencies have prepared a Site Management and Monitoring Plan (SMMP) for the HARS that identifies a number of actions, provisions, and practices to manage remediation activities and monitoring tasks. Part of the planned remediation calls for the placement of a minimum one-meter thick layer of uncontaminated dredged material (defined as Category 1 material) to cap the existing surface sediments within each of nine Priority Remediation Area (PRAs) of the HARS.

The HARS SMMP serves as a guideline document for the monitoring of the PRAs during the course of remediation efforts. The recommended routine monitoring tools in the SMMP include high-resolution bathymetry, REMOTS sediment-profile imaging (SPI), sediment coring, sediment chemistry and toxicity testing, tissue chemistry testing, benthic community analyses, and fish/shellfish surveys. Over the last several years, periodic monitoring surveys have been conducted in the HARS following the guidelines of the SMMP to document dredged material placement activities and overall environmental conditions.

This report presents the results of the summer 2002 survey operations over the 1993 Dioxin Capping Project Mound located near the southern boundary of the former Mud Dump Site. A suite of survey techniques were utilized, including single-beam bathymetry, sub-bottom profiling, side-scan sonar, REMOTS sediment-profile imaging, plan view imaging, benthic grab sampling, and geotechnical and geochemical analysis of sediment vibracores. The survey operations over the 1993 Dioxin Capping Project Mound were one component of a larger summer 2002 monitoring effort at the HARS that included sampling at Priority Remediation Areas (PRAs) 1, 2, and 3, the 1997 Category II Capping Project Mound, and areas of previous red clay disposal. The results of these other survey efforts are presented in separate reports.

1.1 1993 Dioxin Capping Project Background

In 1990, the U.S. Army Corps of Engineers, NYD issued a permit to the Port Authority of New York and New Jersey (PA) for dredging and ocean disposal of approximately 500,000 cubic yards of sediment from berthing areas at the Port Newark/Port Elizabeth container ship terminal in Newark Bay, New Jersey. The sediments to be dredged had been found to contain trace levels of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD, hereinafter called dioxin) and 2,3,7,8-tetrachlorodibenzo-p-furan (2,3,7,8-TCDF, hereinafter called furan). These two

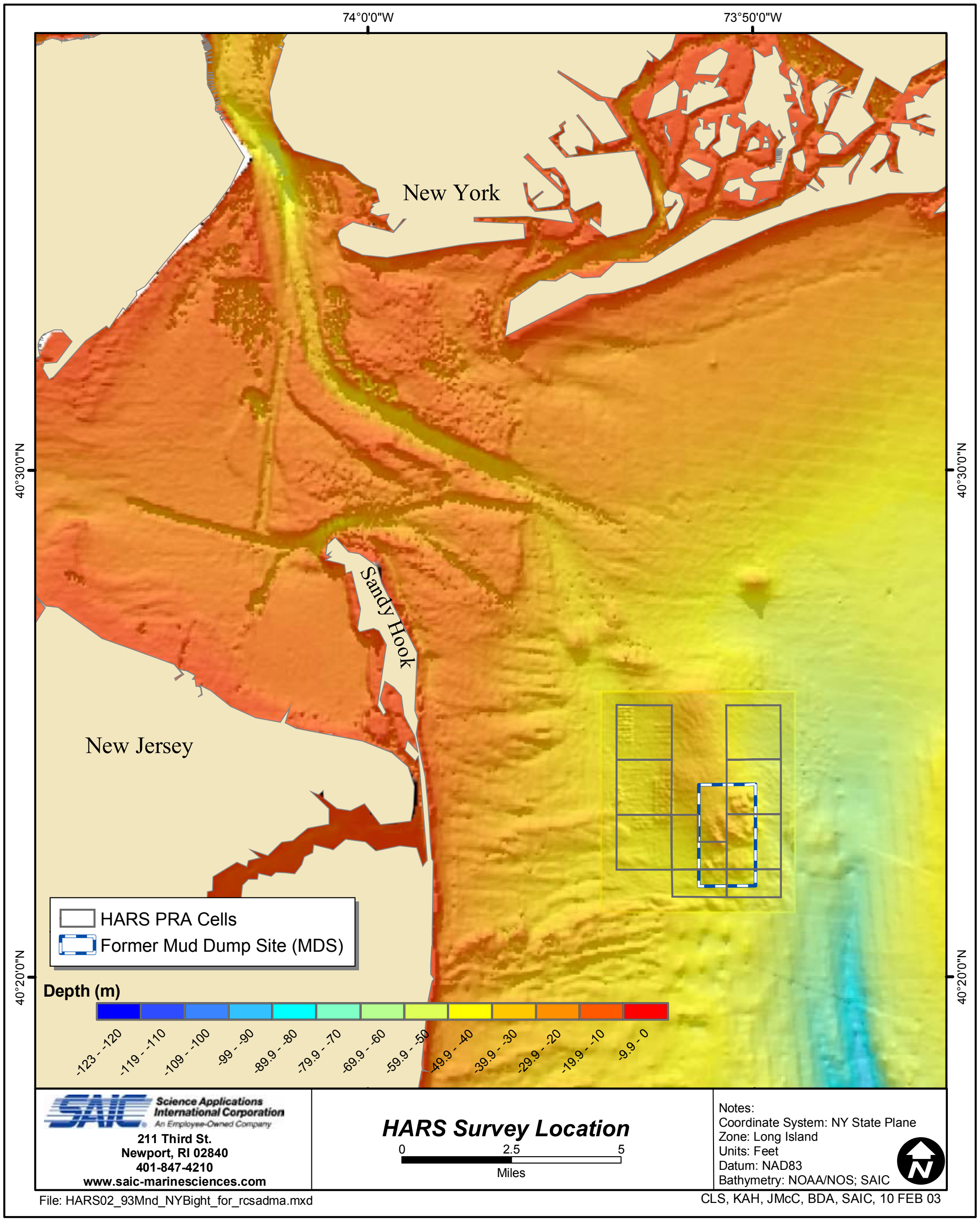


Figure 1.1-1. Map showing the locations of the former Mud Dump Site (MDS) and the Historic Area Remediation Site (HARS) in the New York Bight. The bathymetric contours are from the National Oceanic and Atmospheric Administration (NOAA) Coastal Relief Model Volume 1. The color-coded bathymetric data throughout the wide area surrounding the HARS are from the National Oceanic and Atmospheric Administration (NOAA) Coastal Relief Model Volume 1. The bathymetry at the HARS is from an SAIC survey conducted during summer 2002.

chemicals are forms of classes of compounds known as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzo-p-furans (PCDFs), respectively.

The dioxin-contaminated dredged material from Newark Bay was placed in the southern portion of the former Mud Dump Site (Figure 1.1-2). An estimated 585,500 yd^3 of dredged material was placed at the Mud Dump Site in summer 1993 and subsequently capped with approximately 1.7 million cubic yards of clean sand. The capping operation was completed in February 1994. The NYD and the U.S. EPA developed a comprehensive Monitoring and Management Plan (M&MP) for the Disposal of Dioxin Contaminated Sediments that was implemented over the course of this capping project.

Monitoring was conducted prior to, during, and following both the dredged material disposal and sand capping phases of the project (Figure 1.1-3). The comprehensive suite of monitoring techniques included high-resolution bathymetric surveying, REMOTS sediment-profile imaging, geotechnical analysis of surface sediments and benthic tissue samples from grab samples, geotechnical and geochemical analysis of sediment vibracore samples, sub-bottom profiling of sediment characteristics for mapping of mound stratigraphy, and measurements of wave and currents using moored instruments.

Postcap monitoring at the 1993 Dioxin Mound was conducted at regular intervals, with the most recent surveys taking place in May 1997 (i.e., three years following the completion of the capping operation). This monitoring has served to demonstrate that the cap material has remained in place on the seafloor and has been effective at isolating the underlying dioxin-contaminated sediment. Furthermore, the monitoring has demonstrated that the surface of the cap has been effectively recolonized by benthic organisms.

1.2 2002 Survey Objectives

The overall goal of the 2002 survey effort over the 1993 Dioxin Capping Project Mound was to confirm that the sand cap continues to be present and has remained effective at isolating the underlying dredged material. This will in turn help to determine the need, or lack thereof, for any further placement of remediation material over this mound.

The summer 2002 monitoring effort therefore involved the following survey techniques and objectives:

- High-resolution bathymetric and side-scan sonar data were acquired over the 1993 Dioxin Capping Project Mound to detect changes in topography relative to the results of previous bathymetric surveys, performed at various intervals since 1993 (Figure 1.1-3).

- High-resolution sub-bottom acoustic profiling data were collected over the 1993 Dioxin Mound to identify and measure the thickness of any distinct sedimentary horizons, such as an upper coarse-grained sand cap; a fine-grained underlying dredged material layer, and the underlying ambient substrate. The results were compared to the previous sub-bottom profiling survey performed in late 1993 (Figure 1.1-3).

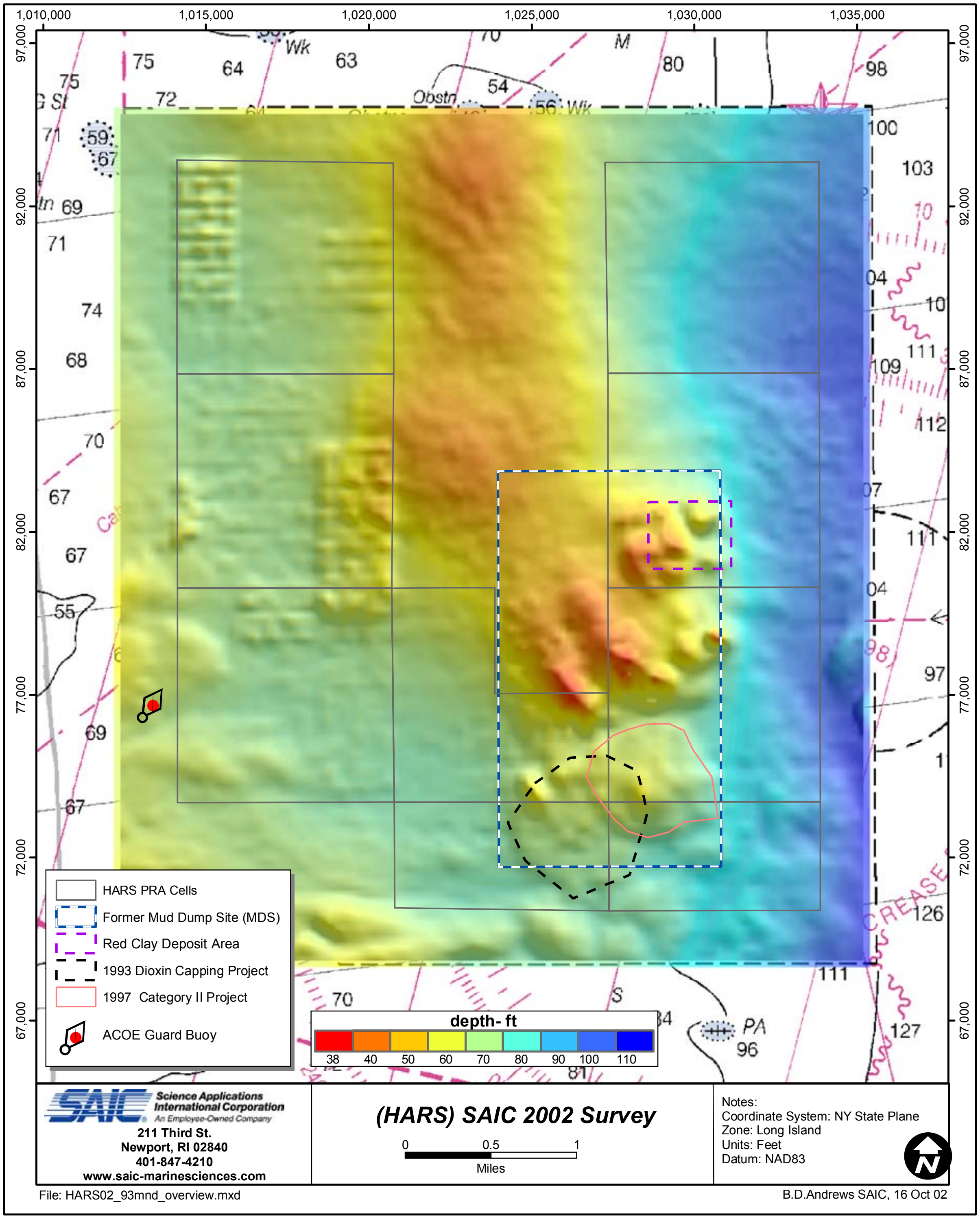


Figure 1.1-2. Location of the 1993 Dioxin Capping Project within the former Mud Dump Site and in relation to the Historic Area Remediation Site. Bathymetry is from the SAIC survey conducted during summer 2002.

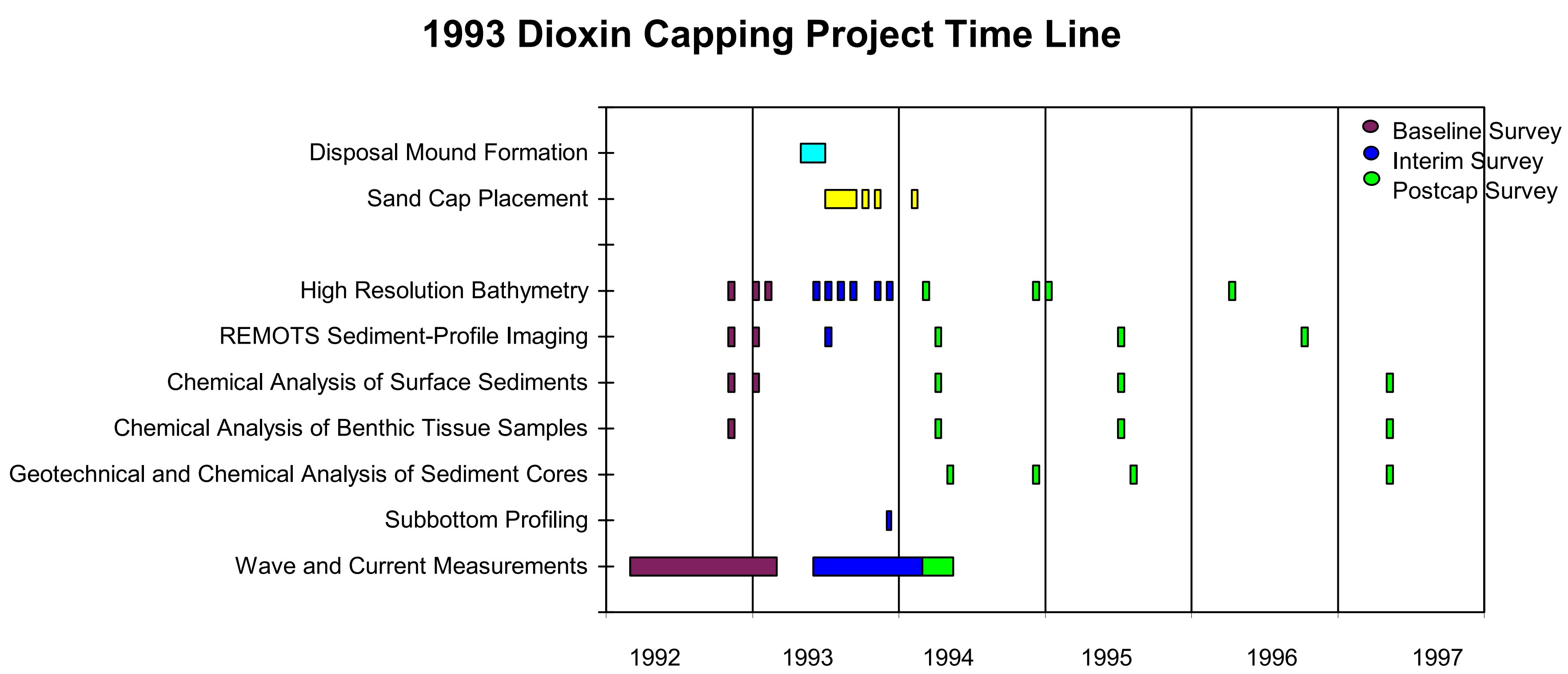


Figure 1.1-3. 1993 Dioxin Mound timeline of material placement and past monitoring surveys

- REMOTS sediment-profile images and corresponding sediment plan view (i.e., downward-looking) images were collected over the capped mound to delineate the distribution of cap material and to assess the benthic recolonization status of the mound. In addition, sediment grab samples were obtained at 10% of the REMOTS stations for taxonomic identification of benthic organisms. The REMOTS stations occupied over the capped mound were identical to those occupied in previous surveys. In addition REMOTS images and benthic grab samples were collected at the South Reference Area located 3 km south of the HARS (Figure 1.2-1). The results from the South Reference Area provide a basis for comparison with the results from the 1993 Dioxin Mound.

- Sediment vibracores were collected at a total of 14 stations located over the 1993 Dioxin Capping Project Mound to determine the thickness of the sand cap layer. Geotechnical and geochemical analysis of samples from selected horizons within each sediment vibracore were used to confirm the long-term effectiveness of the cap material at isolating the underlying dioxin-contaminated sediment.

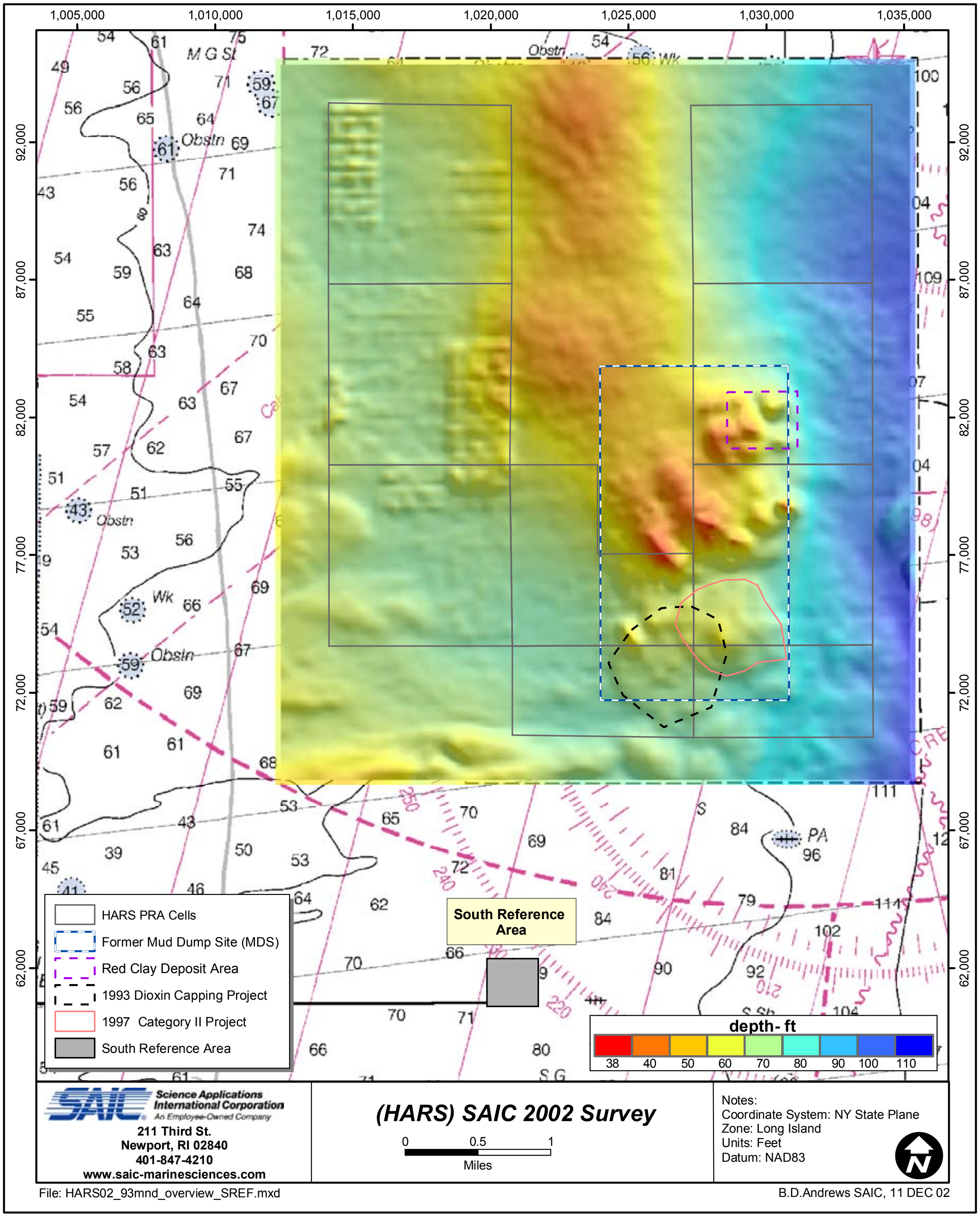


Figure 1.2-1. Location of the South Reference Area in relation to the Historic Area Remediation Site

2.0 METHODS

2.1 Field Operations

The summer 2002 surveys took place between June 19 and September 9, 2002. The M/V *Beavertail* operated by P&M Marine Services of Jamestown, RI was used for the bathymetric, sub-bottom and side-scan sonar surveys, while the M/V *Gelberman,* operated by the USACE NYD, was used for all the other survey work. Detailed methods are provided below for navigation and positioning; bathymetry, side-scan sonar, and sub-bottom profiling; REMOTS sediment-profile and sediment plan view imaging; benthic grab sampling; and sediment vibracoring.

2.2 Navigation and Positioning

Differentially-corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software were used to provide real-time vessel navigation to an accuracy of ±3 m for each survey effort. A Trimble DSMPro GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The DSMPro GPS unit also contains an integrated differential beacon receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Sandy Hook, NJ was utilized for real-time satellite corrections due to its geographic position relative to HARS.

The DGPS data were ported to HYPACK® data acquisition software for position logging and helm display. The target stations and survey lanes were determined prior to the commencement of survey operations and stored in a project database. Throughout the survey, individual stations and survey lanes were selected and displayed to position the survey vessel at the correct geographic location for sampling. To remain on station during the coring survey, the survey vessel was occasionally anchored, in a 2-point configuration. The position of each sample was logged with a time stamp in Universal Time Coordinate (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database for display use. During the bathymetric, side-scan sonar and sub-bottom profile surveys lanes were set up and run within a ±5 m window of the target center line. Vessel positioning was continuously logged during these surveys. DGPS navigation data were received, logged, and displayed in NAD 83 geographic coordinate system.

2.3 Bathymetric Survey

The bathymetric, side-scan sonar, and sub-bottom profile surveys over the 1993 Dioxin Capping Project Mound were completed in conjunction with a larger, more comprehensive survey conducted over the entire HARS from late July 2002 through early September 2002. A detailed discussion of this larger survey is presented in a companion report that provides detailed information on the techniques employed and overall bathymetric data quality (SAIC 2003). An overview of the survey methods employed is provided in the following sections.

2.3.1 Field Methods

Coastal Oceanographic's HYPACKMax® survey and data acquisition software was used to provide the real-time interface, display, and logging of the vessel position and depth sounding data. Prior to field operations, HYPACKMax® was used to define a State Plane grid (New York – Long Island State Plane Coordinates) around the survey area and to establish the planned bathymetric and side-scan survey lanes. During the survey operations, the incoming navigation data were translated into state plane coordinates, time-tagged, and stored within HYPACK®. Depending on the type of field operations being conducted, the real-time navigation information was displayed in a variety of user-defined modes within HYPACKMax®.

Single-beam, bathymetric data, meeting the USACE Class I survey standards (USACE 2002), were acquired over the area encompassing both the 1993 Dioxin Mound and the 1997 Category II Mound (an area measuring approximately 7,100 ft by 12,800 ft) from 16 through 20 August 2002. Depth soundings, as well as sub-bottom profile and side-scan sonar data, were acquired continuously along 71 east-west main-scheme survey lanes spaced at 100 ft intervals (Figure 2.3-1). In addition, single-beam bathymetric data was also acquired along 15 north-south survey lines in conjunction with the side-scan sonar operations on 6 September 2002; the north-south survey lanes provided the data necessary to complete the required cross-check comparisons with the main-scheme bathymetric data (Figure 2.3-1).

During the bathymetric survey operations, the HYPACKMax® survey software was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS. The Hydrotrac® used a narrow-beam (3°), 208-kHz transducer, produced a continuous analog record of the bottom, and transmitted approximately 5 digital depth values per second to HYPACKMax®. Within HYPACKMax®, the time-tagged position and depth data were merged to create continuous depth records along the actual survey track. These records were viewed in real-time to ensure adequate coverage of the survey area.

The echosounder transducer was attached to an over-the-side pole mount that was deployed along the starboard side of the M/V *Beavertail.* An accurate horizontal distance offset was measured between the transducer and DGPS antenna and applied within HYPACKMax® during data acquisition. Though the vessel draft changed slightly during the course of the survey operations due to changes in vessel loading, the transducer draft was maintained at three feet throughout the survey by adjusting the height of the pole. The three-foot draft correction was applied directly to the raw echosounder data within the Hydrotrac® topside recorder and no further draft corrections were applied within HYPACKMax®. Based on settlement and squat tests conducted aboard the M/V *Beavertail* prior to the survey operations, the dynamic draft impacts at standard survey speeds (generally below six knots) were negligible.

A Seabird Electronics SBE-19® conductivity-temperature-depth (CTD) profiler was used to calculate vertical profiles of the water column sound velocity at the beginning, middle, and end of each survey day. On a few of the weather shortened survey days, only two CTD casts were obtained. Typically, at least one of the daily casts was taken in deeper waters along the eastern

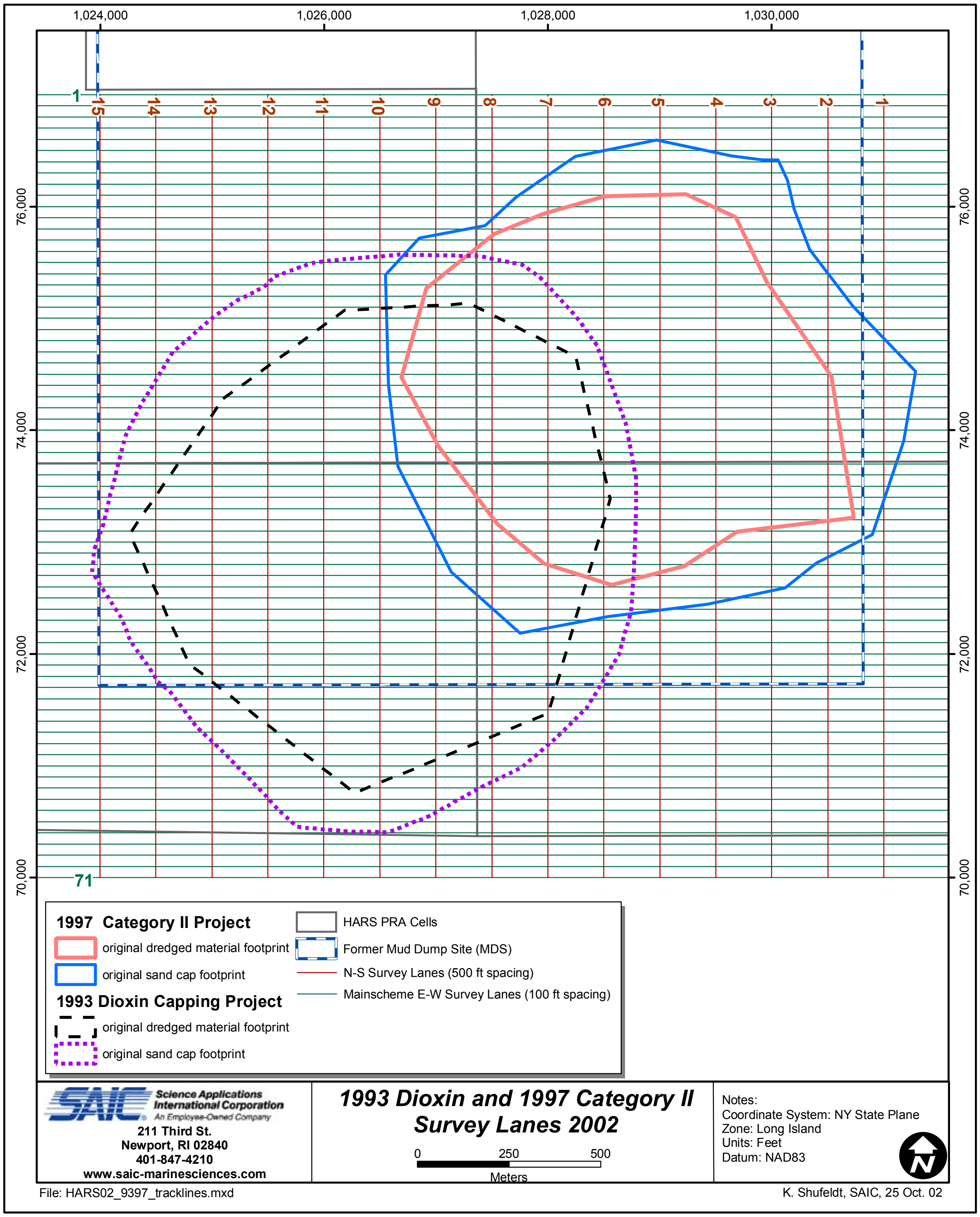


Figure 2.3-1. Survey lanes occupied during the summer 2002 single-beam bathymetry, side-scan sonar, and sub-bottom profile surveys over the 1993 Dioxin Capping Project and 1997 Category II Capping Project Mounds.

edge of the survey area to account for the sound velocity over the full range of depths encountered during the survey. CTD sound velocity data were used to correct the raw echosounder data that were acquired using a constant assumed sound velocity of 4921 ft/sec (1500 m/sec).

To monitor tidal and other water level impacts during this survey, a bottom-mounted tide gauge was deployed along the western buffer zone of the HARS, adjacent to a guard buoy that was deployed by the USACE (Figure 1.1-2). Data from this gauge were used to make comparisons with the data from the primary National Oceanic and Atmospheric Administration (NOAA) tide gauge at Sandy Hook and to help document non-tidal water level differences between the HARS and Sandy Hook Bay. The tide gauge was deployed just prior to the start of survey operations and was recovered after the completion of the last survey lane. The gauge was checked sporadically during the survey and was also retrieved prior to a one-week down period in late August.

2.3.2 Bathymetric Data Processing

The bathymetric data were fully edited and processed using the HYPACKMax® single-beam data processing modules. Raw position and sounding data were edited as necessary to remove or correct questionable data, sound velocity corrections were applied, and the sounding data were reduced to Mean Lower Low Water (MLLW) using observed tides obtained from NOAA.

2.3.2.1 Sound Velocity Corrections

During bathymetric survey data acquisition, an assumed and constant water column sound velocity of 4921 ft/sec (1500 m/sec) was entered into the Odom echosounder. To account for the variable speed of sound through the water column, daily CTD sound velocity casts were taken at the beginning, middle, and end of each survey day. Each CTD cast was processed to produce a one-meter bin-averaged sound velocity profile from the sea surface down to the depth of the cast. The digital CTD cast data were grouped by day and stored within a master spreadsheet file for additional analysis and eventual export into HYPACKMax®.

After the daily sound velocity processing and analysis was completed, the data were used to generate a daily sound velocity profile table within HYPACKMax®. This average sound velocity table was based on a composite of all the casts obtained on a particular day and extended well beyond the deepest depth encountered on the survey. Based on the assumed sound velocity entered into the echosounder during data acquisition and the observed sound velocity reflected in the daily sound velocity profile table, HYPACKMax® computed and applied the required sound velocity corrections to all of the sounding records.

2.3.2.2 Tidal (or Water-Level) Corrections

Observed water level data from the NOAA primary tide station at Sandy Hook, NJ were obtained through NOAA's Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network. The six-minute Sandy Hook tide data were periodically downloaded from the OLLD web site and the appropriate range and phase offsets were applied to transfer these data out to the HARS (http://www.co-ops.nos.noaa.gov). Based on conventions used in the past, a phase offset of –45 minutes and a ratio offset of 0.95 were applied to the observed Sandy Hook time and tidal height data. The corrected Sandy Hook water level data was then used to create daily tidal corrector files within HYPACKMax® that were then used to reduce all of the sounding data to the MLLW vertical datum.

In addition, the on-site bottom-mounted tide gauge was operational throughout the bathymetric survey operations and all tide data were successfully recovered from this gauge. Because the HARS tide gauge data were not referenced to any datum, the data had to be reduced to a consistent vertical datum before it could be compared to the Sandy Hook gauge data. In addition, because this gauge was periodically retrieved during the survey to ensure data recovery, the actual datum shifted slightly after each of these redeployments. Because of this slight datum shift, the HARS tide gauge data were grouped by each of the deployment periods. The final adjusted HARS tide gauge data were merged with the corrected Sandy Hook tide gauge data and grouped together by day within a master tidal spreadsheet for additional daily analysis and eventual export into HYPACKMax®.

2.3.2.3 Cross-Check Comparisons

After the bathymetric data were fully edited and reduced to MLLW, cross-check comparisons on overlapping data were performed to verify the proper application of the correctors and to evaluate the consistency of the data set. The survey pattern used for acquiring the bathymetric survey data yielded an extensive number of cross-check comparisons that could be made on overlapping data points from different survey lanes. Using the HYPACKMax® Statistics utility it was possible to systematically compute the differences between all points from different survey lanes that fell within a user-specified distance of each other. Despite a few feet of sea action during data acquisition, the somewhat irregular seafloor, and the distance separating the survey area from the actual tide station, the cross-check results were consistent for all surveys. A more thorough discussion of the bathymetric data quality results for this survey is presented in the companion report addressing the survey of the entire HARS (SAIC 2003).

2.3.2.4 Data Reduction

After the data were verified, they were then run through the HYPACKMax® Mapper routine to reduce the size of the full data set in a systematic way. Because of the rapid rate at which a survey echosounder can generate data (approximately five depths per second), the along-track data density for a single-beam survey tends to be very high (multiple soundings per meter). In most cases, these data sets contain many redundant data points that can be eliminated without any effect on the overall quality of the data. The Mapper routine examines the full data set along each survey lane and averages all data points that fall within a user-specified grid cell to produce a single average value for each cell. The output from this routine is a merged, ASCII-xyz file that may contain anywhere from 2 to 10% of the original data set. These greatly reduced, but still representative, data sets are far more efficient to use in the subsequent modeling and analysis routines. In addition, the averaging algorithm helps to filter out the impacts of the sea action that was prevalent during most of the survey operations. For this survey, the data were mapped at an interval of 25 ft for later analysis.

2.3.3 Bathymetric Data Analysis and Presentation

The primary intent of this analysis was to evaluate the seafloor surface defined by the bathymetric data in an attempt to identify any unique features and to account for any observed differences with prior surveys. Because single-beam bathymetric survey data typically cover only a small percentage of the total seafloor area (approximately 5%), these analysis tools rely on a large degree of interpolation between the discrete survey data points to generate a three-dimensional seafloor surface model. This interpolation usually works well in flat or gently sloping areas, but in steep and irregular areas the interpolation of the surface can be very dependent upon the orientation of the survey lanes and the density of the data around the area.

The reduced 25-foot averaged trackline data were imported to ArcGIS 8.2 for gridding to a continuous raster surface. The Spatial Analyst extension for ArcGIS was used to explore the variance of the bathymetric trackline data and determine the optimal gridding parameters. Several gridding routines were investigated before final interpolation using Kriging. The Kriging method produces a variance grid along with the calculated surface. This variance grid provides a good indication of how well the chosen Kriging parameters calculated the surface. For this dataset, a 150-foot fixed search radius along with a spherical semivariogram model appeared to provide the best Kriging results (mean variance of 0.48 with a standard deviation of 0.18). The resulting gridded dataset was based on a 200-foot grid cell size and was comprised of 133 rows and 117 columns; this gridded dataset was used for all subsequent analysis and graphics production.

The primary analysis done on the final bathymetric gridded dataset was a depth difference comparison with the most recent prior bathymetric dataset. For the 1993 Dioxin Mound, this prior dataset originated from a postcap monitoring survey conducted in October 1996. Before the depth difference comparisons could be made, the prior dataset had to be reviewed for consistency, modified if necessary, and then gridded based on the same technique outlined in the preceding paragraph. Within ArcGIS 8.2, a bathymetric difference grid was then generated that helped illustrate the magnitude of change within this area since the last survey.

2.4 Sub-bottom Profiling and Side-scan Sonar Survey

2.4.1 Field Methods

The sub-bottom profiling and side-scan sonar survey was conducted over the approximate footprint of the 1993 and 1997 Mounds and was acquired concurrent with the bathymetric data along 71 east-west and 15 north-south survey lanes that encompass the capped mound area (Figure 2.3-1). Sub-bottom profiling and side-scan sonar data were acquired with a Datasonics/Benthos SIS-1000® combined digital sub-bottom profiling and side-scan sonar system that was obtained to support this project from the USACE—Baltimore District. Because the SIS-1000 acquires sub-bottom and side-scan data simultaneously, all of the lanes occupied during the bathymetric survey operations over the capped mound areas (Figure 2.3-1) provided both data types. The SIS-1000 sub-bottom component operates at a swept frequency range of 2 to 7 kHz and the side-scan sonar component operates at a swept frequency range of 90 to 110 kHz. The SIS-1000® fish was towed behind the survey vessel with an armored signal cable that provided power to the towfish and two-way communication with the SIS1000® topside data acquisition system. This system recorded acoustic data from the towfish and position information from the navigation system, and displayed real-time sub-bottom imagery on a PC monitor.

Sub-bottom profiling is a standard technique used for distinguishing and measuring various sediment layers that exist below the sediment/water interface. Sub-bottom systems are able to distinguish these sediment layers by measuring differences in acoustic impedance between the layers. Acoustic impedance is a function of the density of a layer and speed of sound within that layer and is affected by differences in grain size, roughness, and porosity. Sound energy transmitted to the seafloor is reflected off the boundaries between sediment layers of different acoustic impedance. A sub-bottom system uses the energy reflected from these boundary layers to build the image. The depth of penetration and the degree of resolution of a sub-bottom system depends on the frequency and pulse width of the acoustic signal and the characteristics of the various layers encountered. In addition, because of the strength of the acoustic return signal normally associated with the seafloor reflector, it is often difficult to clearly distinguish sub-bottom horizons that are within a few feet of the seafloor surface.

Side-scan sonar systems provide an acoustic image of the seafloor by detecting the strength of the backscatter returns from signals emitted from a towed side-scan sonar transducer array. The side-scan transducers operate similar to a conventional depth-sounding transducer except that the towfish has a pair of opposing transducers aimed perpendicular to and directed on either side of the vessel track. Side-scan sonar data can reveal general seafloor characteristics and also provide the size and location of distinct objects. Dense objects (e.g., metal, rocks, coarse sand seafloor areas) will reflect strong signals and appear as dark areas in the records presented in this report. Conversely, areas characterized by soft features (e.g., silt, mud, or fine sand sediments), which absorb sonar energy, appear as light areas in the sample records.

2.4.2 Sub-bottom Profiling Data Processing and Analysis

Although sub-bottom data was acquired and recorded concurrent with all bathymetric survey operations over the mound areas, a file-formatting problem associated the older SIS-1000® topside operating system made it difficult to analyze any of the initial digital sub-bottom data acquired along the east-west survey lanes. Though a standard XTF file format was specified for storing this data within the SIS-1000® topside unit, this older XTF format was not compatible with the XTF file format supported by recent versions of available sub-bottom image analysis packages. After the data incompatibility issues were discovered, the SIS-1000® was returned to Datasonics/Benthos for evaluation and upgrade. Because a complete system upgrade was cost prohibitive under this contract (estimated at $40K), a minor modification was made to upgrade only the file formatting capability. During the subsequent north-south survey lanes run towards the end of this project, an older QMIPS file format was used to record the digital sub-bottom data.

After data acquisition, the sub-bottom data were analyzed and edited as necessary using the Chesapeake Technologies SonarWeb® software; some minor modifications were necessary to SonarWeb® to accommodate the older QMIPS data format. Because of the file formatting problems associated with the east-west sub-bottom data, most of the initial sub-bottom processing was focused on the north-south data. (Some of the east-west data were viewed manually to help confirm or enhance the north-south results.) SonarWeb® enables manual detection, tracking, and digitizing of any sub-bottom layers that are present in the data and also allows the data to be re-displayed under a variety of different configurations.

The process of digitizing sub-bottom reflectors using the SonarWeb® software created individual comma delimited (CSV) files containing digitized points along the lane. Information in these files included the reflector name, reflector description, position (x and y) of each point, and depth (z) of each point relative to the towfish (not the actual depth). Identified sub-bottom reflectors included: the seafloor, the sand cap/dredged material interface, potential sand cap layers, and the possible dredged material/ambient sediment interface. Sporadic data gaps typically existed in these digitized files where the sub-bottom horizon could not be clearly distinguished and digitized.

Upon completion of the sub-bottom reflector processing in SonarWeb®, the data were sorted into individual comma delimited files according to reflector type to facilitate Geographic Information System (GIS) processing. Although the depth of a reflector is the distance from the towfish and not the actual depth, the thickness of sediment layers (i.e., cap material) could still be measured. The distance (depth) from the seafloor reflector to the cap interface reflector was measured to obtain a cap thickness. This process was completed using the ArcInfo® Grid module to generate a gridded data model for each surface based on the data set and a user-defined grid cell size. A surface model was created for the seafloor reflector data set and the cap interface reflector data set. The difference between these surfaces was used to generate a calculated cap thickness map. The surface model of cap thickness was then imported into ArcView® for additional analysis and review, and to generate graphic products incorporating some of the other survey datasets.

In former sub-bottom surveys over both the 1993 and 1997 Mounds, the speed of sound in the cap material was estimated in order to better calibrate the acoustic sub-bottom data (SAIC 1994, SAIC 1998). In these previous surveys, an estimate of 1711 m/sec was used for the speed of sound when post-processing this data. An increase in the assumed speed of sound up to 1711 m/sec leads to an apparent increase in the cap thickness of 14% above the thickness values indicated when an assumed speed of sound of 1500 m/sec is used. When this 14% increase was applied to the 2002 sub-bottom results, greater differences were noted between the acoustic cap thickness values and the coring cap thickness results. Because it provided better overall agreement with the coring results and a more conservative estimate of cap thickness, an assumed speed of sound of 1500 m/sec was used for generating the final acoustic cap thickness values.

2.4.3 Side-Scan Sonar Data Processing and Analysis

Though not specified as a technical component of this contract, the side-scan sonar data was acquired during the SIS-1000 sub-bottom profiling operations. During the survey, the data from each survey lane was saved into a separate file to facilitate post-processing. During post-processing, each north-south survey lane was re-played within SonarWeb®, water column and time varied gain (TVG) adjustments were made, and then the data were merged together using the SonarWeb® mosaic utility. After the mosaic was completed, it was saved and exported as a geo-referenced Tagged Image File Format (TIFF) file. The geo-referenced TIFF of the final mosaic was then imported into a GIS for spatial analysis.

2.5 REMOTS Sediment-Profile and Sediment Plan View Imaging

2.5.1 Sampling Design and Field Methods

A total of 60 REMOTS sediment-profile imaging (SPI) stations were occupied during the June 2002 postcap survey. Fifty (50) of the stations were located on and adjacent to the 1993 Dioxin Mound and 10 stations were located within the nearby South Reference Area (Tables 2.5-1 and 2.5-2; Figures 1.2-1 and 2.5-1). The South Reference Area was centered at 40°20.130′ N, 73°52.170′ W. The June 2002 station locations were identical to those occupied during the three previous postcap REMOTS SPI surveys performed in April 1994, July 1995, and October 1996, respectively (SAIC 1995a; SAIC 1996; SAIC 1997).

The 50 stations located in and around the 1993 Dioxin Mound were divided into three areas (Figure 2.5-1) based on the objectives of past surveys and include:

1. Area A or the capped mound area was defined by the boundaries of the dredged material footprint within which a minimum of one meter of sand cap material was required;

2. Area B, located to the north and west of the required cap area. This area was previously sampled during the baseline REMOTS surveys of November 1992 and January 1993;

3. Area C, located to the south and east of the capped area. This area was not sampled during the baseline REMOTS surveys but was sampled during the three previous postcap REMOTS surveys.

Sampling locations within the project area originally were selected by random distribution within a grid of 384 cells, each measuring approximately 85 x 85 m. Zone A incorporated 174 cells of which 25 were sampled. In Areas B and C, 13 of 74 cells, and 12 of 136 cells were sampled, respectively. Sampling within the South Reference Area was based on a random distribution of ten stations within a 500 m x 500 m grid having 100 cells.

During all survey operations, at least two replicate sediment-profile images and one plan view image were collected at each station. Color slide film was used and developed at the end of each field day to verify proper equipment operation and image acquisition.

2.5.2 REMOTS Sediment-Profile Image Acquisition

REMOTS sediment-profile imaging is a formal and standardized technique for sediment-profile imaging and analysis (Rhoads and Germano 1982; 1986). A Benthos Model 3731 Sediment-Profile Camera (Benthos, Inc., North Falmouth, MA) was used in this study (Figure 2.5-2). The camera is designed to obtain in situ profile images of the top (20 cm) of seafloor sediment. Functioning like an inverted periscope, the camera consists of a wedge-shaped prism with a front face-plate and a back mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface facing the camera. The prism is filled with distilled water, the assembly contains

Table 2.5-1.
Coordinates of REMOTS Stations (Areas A, B, and C)
within the 1993 Dioxin Capping Project Mound Area (NAD 83).
Shading indicates REMOTS/Benthic Grab Stations.

Station	Latitude	Longitude	Northing	Easting	Station	Latitude	Longitude	Northing	Easting
a1	40.3711	73.8475	74513	1026752	b1	40.3739	73.8524	75550	1025383
a2	40.3703	73.8524	74237	1025385	b2	40.3733	73.8571	75329	1024071
a3	40.3703	73.8426	74242	1028119	b3	40.3733	73.8543	75330	1024837
a4	40.3696	73.8534	73964	1025112	b4	40.3733	73.8514	75332	1025657
a5	40.3696	73.8485	73966	1026479	b5	40.3733	73.8475	75334	1026750
a6	40.3681	73.8514	73418	1025660	b6	40.3726	73.8553	75056	1024564
a7	40.3681	73.8494	73419	1026207	b7	40.3726	73.8514	75058	1025657
a8	40.3681	73.8465	73420	1027027	b8	40.3718	73.8571	74782	1024072
a9	40.3673	73.8524	73144	1025387	b9	40.3711	73.8534	74510	1025111
a10	40.3673	73.8485	73146	1026481	b10	40.3673	73.8571	73142	1024075
a11	40.3673	73.8445	73148	1027574	b11	40.3666	73.8563	72868	1024294
a12	40.3673	73.8416	73149	1028394	b12	40.3651	73.8571	72321	1024076
a13	40.3666	73.8475	72873	1026754	b13	40.3651	73.8563	72322	1024295
a14	40.3666	73.8455	72874	1027301	c1	40.3739	73.8426	75555	1028116
a15	40.3666	73.8445	72874	1027574	c2	40.3739	73.8406	75556	1028663
a16	40.3658	73.8455	72600	1027302	c3	40.3739	73.8398	75556	1028882
a17	40.3651	73.8524	72324	1025389	c4	40.3718	73.8406	74790	1028665
a18	40.3643	73.8504	72051	1025936	c5	40.3703	73.8398	74244	1028884
a19	40.3636	73.8524	71777	1025390	c6	40.3651	73.8406	72329	1028669
a20	40.3628	73.8504	71504	1025937	c7	40.3621	73.8553	71229	1024570
a21	40.3628	73.8494	71505	1026210	c8	40.3621	73.8534	71229	1025117
a22	40.3628	73.8485	71505	1026483	c9	40.3613	73.8435	70961	1027851
a23	40.3628	73.8465	71506	1027030	c10	40.3613	73.8406	70962	1028671
a24	40.3621	73.8455	71233	1027296	c11	40.3598	73.8571	70407	1024080
a25	40.3613	73.8485	70958	1026484	c12	40.3592	73.8426	70196	1028126

Table 2.5-2.
Coordinates of REMOTS Stations at the South Reference Area (NAD 83).
Shading indicates REMOTS/Benthic Grab Stations.

Station	Latitude	Longitude	Northing	Easting
s3	40.3372	73.8711	62150	1020175
s4	40.3372	73.8670	62152	1021324
s5	40.3367	73.8700	61987	1020504
s8	40.3358	73.8700	61658	1020504
s10	40.3358	73.8676	61659	1021160
s11	40.3354	73.8711	61494	1020176
s14	40.3340	73.8711	61002	1020177
s16	40.3340	73.8694	61002	1020669
s18	40.3340	73.8682	61003	1020997
s20	40.3336	73.8670	60839	1021326

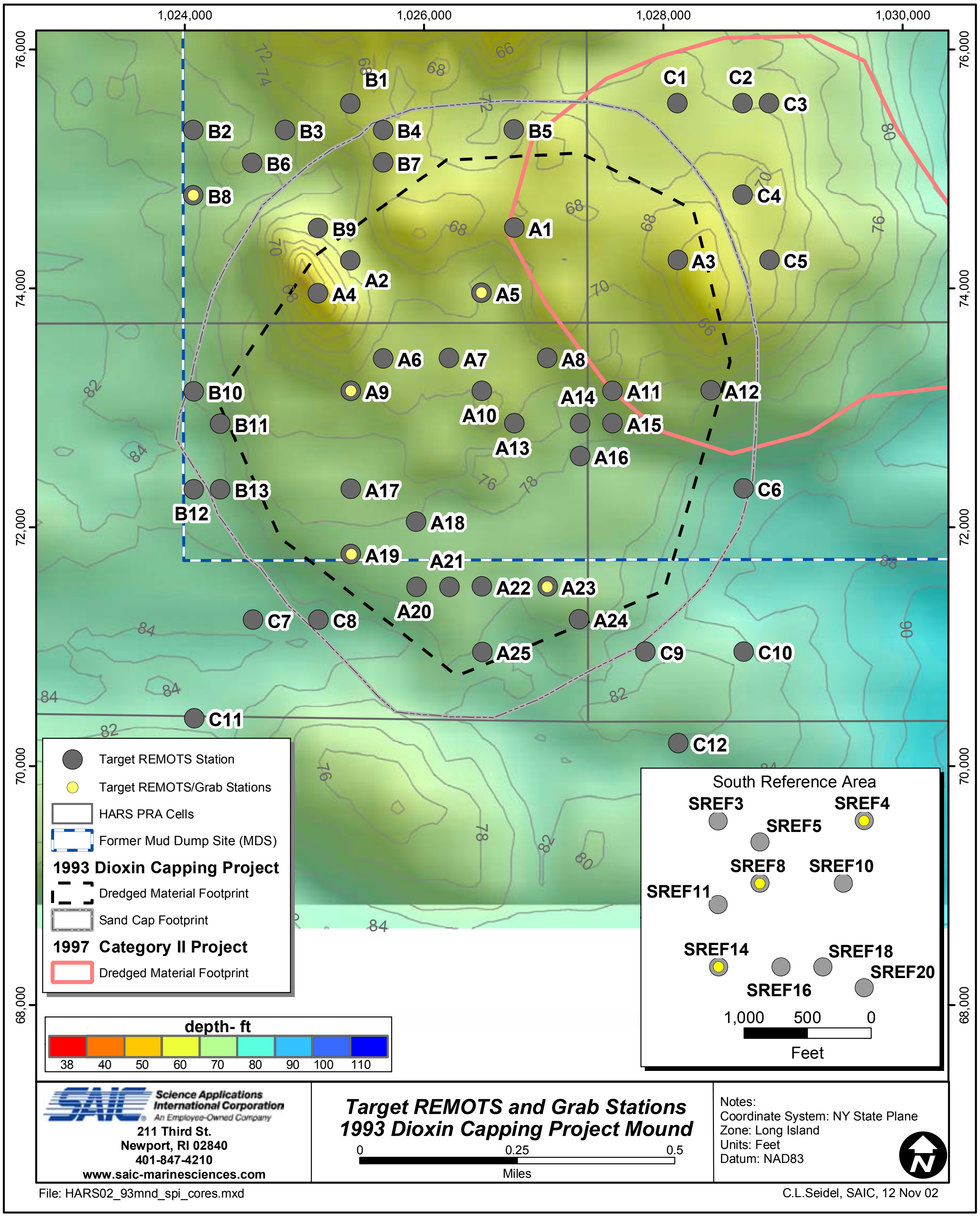


Figure 2.5-1. Location of the 2002 REMOTS and benthic grab sampling stations over the 1993 Dioxin Capping Project Mound Area and the nearby South Reference Area

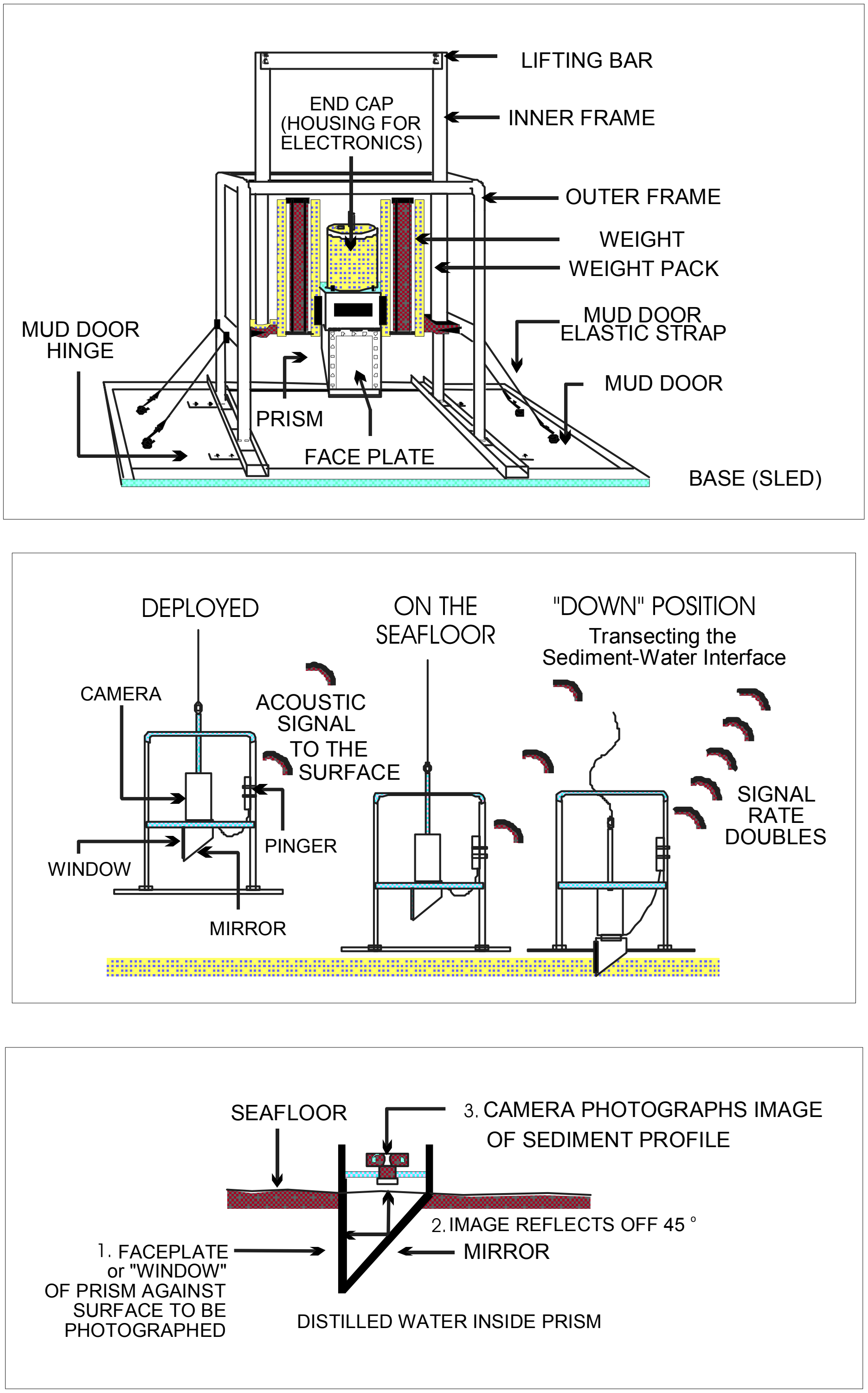


Figure 2.5-2. Schematic diagram of Benthos, Inc. Model 3731 REMOTS sediment-profile camera and sequence of operation on deployment

an internal strobe used to illuminate the images, and a 35-mm camera is mounted horizontally on top of the prism. The prism assembly is moved up and down into the sediments by producing tension or slack on the winch wire. Tension on the wire keeps the prism in the up position, out of the sediment.

The camera frame is lowered to the seafloor at a rate of approximately 1 m/sec (Figure 2.5-2). When the frame settles onto the seafloor, slack on the winch wire allows the prism to penetrate the seafloor vertically. A passive hydraulic piston ensures that the prism enters the bottom slowly (approximately 6 cm/sec) and does not disturb the sediment-water interface. As the prism starts to penetrate the seafloor, a trigger activates a 13-second time delay on the shutter release to allow maximum penetration before a photo is taken.

A Benthos Model 2216 Deep Sea Pinger is normally attached to the camera to output a 12 kHz signal once per second; upon discharge of the camera strobe, the ping rate doubles for a period of 10 seconds. By monitoring the pinger's repetition rate from the surface vessel, one can confirm that a successful image was obtained. Because the sediment photographed is directly against the face plate, turbidity of the ambient seawater does not affect image quality. When the camera is raised, a wiper blade cleans off the faceplate, the film is advanced by a motor drive, the strobe is recharged, and the camera can be lowered for another image. At least two replicate sediment-profile images were obtained at each station using color slide film (Kodak Ektachrome). The film was developed at the end of each day of field operations to verify that the equipment was operating properly and all necessary data were acquired.

2.5.3 REMOTS Sediment-Profile Image Analysis

A computerized image analysis system was used to analyze the images. The original sediment-profile images (35-mm slides) were scanned and imported digitally into the image analysis system for measurement of a suite of up to 21 standard biological and physical parameters. The data for each image were stored automatically in a centralized database and exported in various formats (data tables and reports) to be compared statistically and mapped using Arcview GIS. All measurements were reviewed (quality assurance check) before being approved for final data synthesis, statistical analyses, and interpretation. Summaries of the standard REMOTS measurement parameters presented in this report are presented below.

2.5.3.1 Sediment Type Determination

The sediment grain-size major mode and range are estimated visually from the photographs by overlaying a grain size comparator of the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the REMOTS sediment-profile camera. Seven grain size classes are on this comparator: >4 phi, 4 to 3 phi, 3 to 2 phi, 2 to 1 phi, 1 to 0 phi, 0 to –1 phi, and <-1 phi. Table 2.5-3 is provided to allow conversion of phi units to other commonly used grain size scales. The lower limit of optical resolution of the photographic system is about 62 microns (4 phi), allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing REMOTS sediment-profile image estimates with grain size statistics determined from laboratory sieve analyses.

Table 2.5-3.
Grain Size Scales for Sediments

ASTM (Unified) Classification [1]	U.S. Std. Mesh [2]	Size in mm	PHI Size	Wentworth Classification [3]
Boulder		4096.	-12.0	
		1024.	-10.0	Boulder
	12 in (300 mm)	256.	-8.0	
		128.	-7.0	Large Cobble
Cobble		107.64	-6.75	
		90.51	-6.5	Small Cobble
	3 in. (75 mm)	76.11	-6.25	
		64.00	-6.0	
		53.82	-5.75	
		45.26	-5.5	Very Large Pebble
Coarse Gravel		38.05	-5.25	
		32.00	-5.0	
		26.91	-4.75	
		22.63	-4.5	Large Pebble
	3/4 in (19 mm)	19.03	-4.25	
		16.00	-4.0	
		13.45	-3.75	
		11.31	-3.5	Medium Pebble
Fine Gravel		9.51	-3.25	
	2.5	8.00	-3.0	
	3	6.73	-2.75	
	3.5	5.66	-2.5	Small Pebble
	4	4.76	-2.25	
	5	4.00	-2.0	
Coarse Sand	6	3.36	-1.75	
	7	2.83	-1.5	Granule
	8	2.38	-1.25	
	10	2.00	-1.0	
	12	1.68	-0.75	
	14	1.41	-0.5	Very Coarse Sand
	16	1.19	-0.25	
Medium Sand	18	1.00	0.0	
	20	0.84	0.25	
	25	0.71	0.5	Coarse Sand
	30	0.59	0.75	
	35	0.50	1.0	
	40	0.420	1.25	
	45	0.354	1.5	Medium Sand
	50	0.297	1.75	
	60	0.250	2.0	
	70	0.210	2.25	
Fine Sand	80	0.177	2.5	Fine Sand
	100	0.149	2.75	
	120	0.125	3.0	
	140	0.105	3.25	
	170	0.088	3.5	Very Fine Sand
	200	0.074	3.75	
	230	0.0625	4.0	
Fine-grained Soil:	270	0.0526	4.25	
	325	0.0442	4.5	Coarse Silt
Clay if PI ≥ 4	400	0.0372	4.75	
Silt if PI < 4		0.0312	5.0	Medium Silt
		0.0156	6.0	Fine Silt
		0.0078	7.0	Very Fine Silt
		0.0039	8.0	Coarse Clay
		0.00195	9.0	Medium Clay
		0.00098	10.0	Fine Clay
		0.00049	11.0	
		0.00024	12.0	
		0.00012	13.0	
		0.000061	14.0	

1. ASTM Standard D 2487-92. This is the ASTM version of the Unified Soil Classification System. Both systems are similar (from ASTM (1993)).
2. Note that British Standard, French, and German DIN mesh sizes and classifications are different.
3. Wentworth sizes (in inches) cited in Krumbein and Sloss (1963).

Source: U.S. Army Corps of Engineers. (1995). Engineering and Design Coastal Geology, "Engineer Manual 1110-2-1810, Washington, D.C.

The major modal grain size that is assigned to an image is the dominant grain size as estimated by area within the imaged sediment column. In those images that show layering of sand and mud, the dominant major mode assigned to a replicate therefore depends on how much area of the image is represented by sand versus mud. These textural assignments may or may not correspond to traditional sieve analyses depending on how closely the vertical sampling intervals are matched between the grab or core sample and the depth of the imaged sediment. Layering is noted as a comment accompanying the REMOTS sediment-profile image data file.

2.5.3.2 Benthic Habitat Classification

Based on extensive past REMOTS sediment-profile survey experience in coastal New England, five basic benthic habitat types have been found to exist in shallow-water estuarine and open-water near shore environments: AM = Ampelisca mat, SH = shell bed, SA = hard sand bottom, HR = hard rock/gravel bottom, and UN = unconsolidated soft bottom (Table 2.5-4). Several sub-habitat types exist within these major categories (Table 2.5-4). Each of the REMOTS sediment-profile images obtained in the present study was assigned one of the habitat categories listed in Table 2.5-4.

2.5.3.3 Mud Clasts

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in REMOTS sediment-profile images. During image analysis, the number of clasts are counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. Also, once at the sediment-water interface, these sediment clumps are subject to bottom-water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6–12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g., angular versus rounded, are also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

2.5.3.4 Sedimentary Methane

At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in REMOTS sediment-profile images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total areal coverage of all methane pockets are measured.

Table 2.5-4.
Benthic Habitat Categories Assigned to
Sediment-Profile Images Obtained in this Study

Habitat AM: *Ampelisca* Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (*Ampelisca* spp.) tube mats at the sediment-water interface.
Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: **SH.SI: Shell Bed over silty sediment** - shell layer overlying sediments ranging from fine sands to silts to silt-clay. **SH.SA: Shell Bed over sandy sediment** - shell layer overlying sediments ranging from fine to coarse sand.
Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments, do not appear to be bioturbated, bedforms common, successional stage mostly indeterminate because of low prism penetration. **SA.F: Fine sand** - uniform fine sand sediments (grain size: 4 to 3 phi). **SA.M: Medium sand** - uniform medium sand sediments (grain size: 3 to 2 phi). **SA.G: Medium sand with gravel** - predominately medium to coarse sand with a minor gravel fraction.
Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty-sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates).
Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (I, II and III). Biogenic features were common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: **UN.SS: Fine Sand/Silty** - very fine sand mixed with silt (grain size range from 4 to 2 phi), with little or no shell hash. **UN.SI: Silty** - homogeneous soft silty sediments (grain size range from >4 to 3 phi), with little or no shell hash. Generally deep prism penetration. **UN.SF: Very Soft Mud** - very soft muddy sediments (>4 phi) of high apparent water content, methane gas bubbles present in some images, deep prism penetration.

2.5.3.5 Measurement of Dredged Material and Cap Layers

The recognition of dredged material from REMOTS sediment-profile images is usually based on the presence of anomalous sedimentary materials within an area of ambient sediment. The ability to distinguish between ambient sediment and dredged or cap material demands that the survey extend well beyond the margins of a disposal site so that an accurate characterization of the ambient bottom is obtained. The distributional anomalies may be manifested in topographic roughness, differences in grain size, sorting, shell content, optical reflectance, fabric, or sediment compaction (i.e., camera prism penetration depth). Second-order anomalies may also provide information about the effects of dredged material on the benthos and benthic processes such as bioturbation (see following sections).

2.5.3.6 Boundary Roughness

Small-scale boundary roughness is measured from an image with the computer image analysis system. This vertical measurement is from the highest point at the sediment-water interface to the lowest point. This measurement of vertical relief is made within a horizontal distance of 15 cm (the total width of the optical window). Because the optical window is 20 cm high, the greatest possible roughness value is 20 cm. The source of the roughness is described if known. In most cases this is either biogenic (mounds and depressions formed by bioturbation or foraging activity) or relief formed by physical processes (ripples, scour depressions, rip-ups, mud clasts, etc.).

2.5.3.7 Optical Prism Penetration Depth

The optical prism of the REMOTS sediment-profile camera penetrates the bottom under a static driving force imparted by its weight. The penetration depth into the bottom depends on the force exerted by the optical prism and the bearing strength of the sediment. If the weight of the camera prism is held constant, the change in penetration depth over a surveyed region will reflect horizontal variability in geotechnical properties of the seafloor. In this sense, the camera prism acts as a static-load penetrometer. The depth of penetration of the optical prism into the bottom can be a useful parameter, because dredged and capped materials often have different shear strengths and bearing capacities.

2.5.3.8 Infaunal Successional Stage

Determination of the infaunal successional stage applies only to soft-bottom habitats, where the REMOTS camera is able to penetrate into the sediment. In hard bottom environments (i.e., rocky substrates), camera penetration is prevented and the standard suite of REMOTS measurements cannot be made. In such instances, the infaunal successional stage is considered to be "indeterminate." Hard bottom areas can support abundant and diverse epibenthic communities and therefore may represent habitat which is biologically productive or otherwise is of value as refuge or living space for organisms. However, the value of hard bottom habitats is not reflected in the REMOTS successional stage designation.

The mapping of infaunal successional stages is based on the theory that organism-sediment interactions in marine soft-bottom habitats follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, disturbance by bottom trawlers, dredged material deposition, hypoxia). The theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is formally developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

Benthic disturbance can result from natural processes, such as seafloor erosion, changes in seafloor chemistry, and predator foraging, as well as from human activities like dredged material or sewage sludge disposal, thermal effluent from power plants, bottom trawling, pollution from industrial discharge, and excessive organic loading. Evaluation of successional stages involves deducing dynamics from structure, a technique pioneered by R. G. Johnson (1972) for marine soft-bottom habitats. The application of this approach to benthic monitoring requires *in situ* measurements of salient structural features of organism-sediment relationships as imaged through REMOTS technology.

Pioneering assemblages (Stage I assemblages) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes (Figure 2.5-3); alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary; and bioturbation depths are shallow, particularly in the earliest stages of colonization (Figure 2.5-3). In the absence of further disturbance, these early successional assemblages are eventually replaced by infaunal deposit feeders; the start of this "infaunalization" process is designated arbitrarily as Stage II. Typical Stage II species are shallow dwelling bivalves or, as is common in New England waters, tubicolous amphipods. In studies of hypoxia-induced benthic defaunation events in Tampa Bay, Florida, Ampeliscid amphipods appeared as the second temporal dominant in two of the four recolonization cycles (Santos and Simon 1980a, 1980b).

Stage III taxa, in turn, represent high-order successional stages typically found in low-disturbance regimes. These invertebrates are infaunal, and many feed at depth in a head-down orientation. The localized feeding activity results in distinctive excavations called feeding voids (Figure 2.5-3). Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. This granulometric change is caused by the accumulation of coarse particles that are rejected by the animals feeding selectively on fine-grained material. Other subsurface structures, such as burrows or methane gas bubbles, do not exhibit these characteristics and therefore are quite distinguishable from these distinctive feeding structures. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment. In the retrograde transition of Stage III to Stage I, it is sometimes possible to recognize the presence of relict (i.e., collapsed and inactive) feeding voids.

The end-member stages (Stages I and III) are easily recognized in REMOTS images by the presence of dense assemblages of near-surface polychaetes (Stage I) or the presence of subsurface feeding voids (Stage III; Figure 2.5-3). The presence of tubicolous amphipods at the

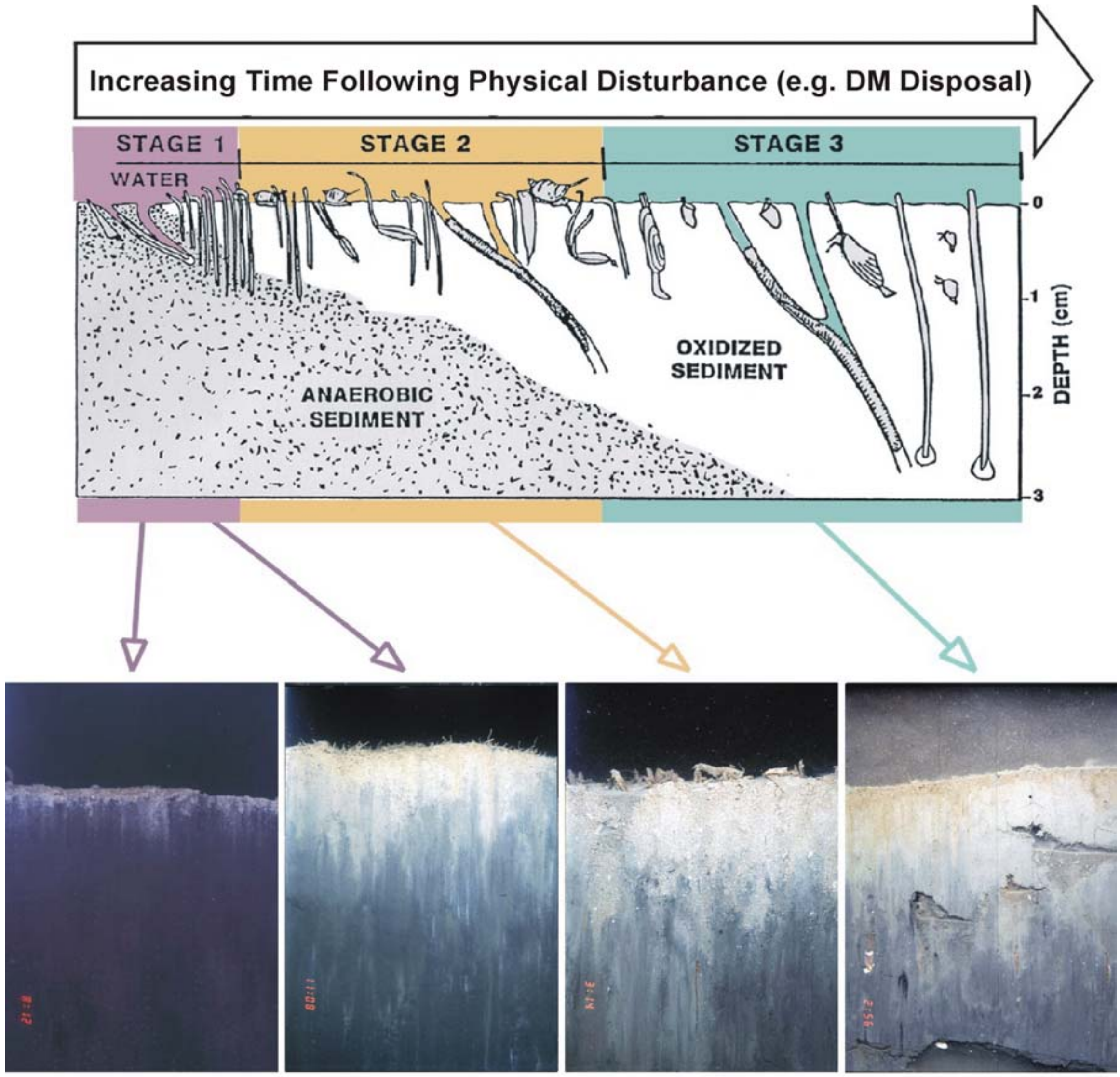


Figure 2.5-3. The drawing at the top illustrates the development of infaunal successional stages over time following a physical disturbance or with distance from an organic loading source (from Rhoads and Germano 1986). The REMOTS images below the drawing provide examples of the different successional stages. Image A shows highly reduced sediment with a very shallow redox layer (contrast between light colored surface sediments and dark underlying sediments) and little evidence of infauna. Numerous small polychaete tubes are visible at the sediment surface in image B (Stage I), and the redox depth is deeper than in image A. A mixture of polychaete and amphipod tubes occurs at the sediment surface in image C (Stage II). Image D shows numerous burrow openings and feeding pockets (voids) at depth within the sediment; these are evidence of deposit-feeding, Stage III infauna. Note the aRPD is relatively deep in this image, as bioturbation by the Stage III organisms has resulted in increased sediment aeration, causing the redox horizon to be located several centimeters below the sediment-water interface.

sediment surface is indicative of Stage II. It is possible for Stage I polychaetes or Stage II tubicolous amphipods to be present at the sediment surface, while at the same time, Stage III organisms are present at depth within the sediment. In such instances, where two types of assemblages are visible in a REMOTS image, the image is designated as having either a Stage I on Stage III (I–III) or Stage II on Stage III (II–III) successional stage. Additional information on REMOTS image interpretation can be found in Rhoads and Germano (1982, 1986).

2.5.3.9 Apparent Redox Potential Discontinuity Depth

Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying anoxic sediments. Sand also has higher optical reflectance than mud. These differences in optical reflectance are readily apparent in REMOTS sediment-profile images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black. The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent redox potential discontinuity (aRPD).

The depth of the aRPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) which separates the positive Eh region (oxidized) from the underlying negative Eh region (reduced) can only be determined accurately with microelectrodes. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD (aRPD), and it is mapped as a mean value.

The depression of the aRPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore, this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the aRPD is also slow (Germano 1983). Measurable changes in the aRPD depth using the REMOTS sediment-profile image optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients), which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. In sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS (Disposal Area Monitoring System) Program for the USACE, New England Division, SAIC repeatedly has documented a drastic reduction in aRPD depths at disposal sites immediately after dredged material disposal, followed by a progressive postdisposal aRPD deepening (barring further physical disturbance). Consequently, time-series aRPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean aRPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin aRPD depths. During storm periods, erosion may completely remove any evidence of the aRPD (Fredette et al. 1988).

Another important characteristic of the aRPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly reduced (lower reflectance) sediments at depth and higher aRPD contrasts. In a region of generally low aRPD contrasts, images with high aRPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

2.5.3.10 Organism-Sediment Index (OSI)

The multi-parameter REMOTS Organism-Sediment Index (OSI) has been constructed to characterize benthic habitat quality. Benthic habitat quality is defined relative to two end-member standards. The lowest value is given to those bottoms which have low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment (see Rhoads and Germano 1982, 1986, for REMOTS criteria for these conditions). The OSI for such a condition is –10 (highly disturbed or degraded benthic habitat quality). At the other end of the scale, an aerobic bottom with a deeply depressed aRPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have an OSI value of +11 (unstressed or undisturbed benthic habitat quality).

The OSI is a sum of the subset indices shown in Table 2.5-5. The OSI is calculated automatically by SAIC software after completion of all measurements from each REMOTS photographic negative. The index has proven to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance (Germano and Rhoads 1984, Revelas et al. 1987, Valente et al. 1992).

The OSI may be subject to seasonal changes because the mean aRPD depths vary as a result of temperature-controlled changes of bioturbation rates and sediment oxygen demand. Furthermore, the successional status of a station may change over the course of a season related to recruitment and mortality patterns or the disturbance history of the bottom. The sub-annual change in successional status is generally limited to Stage I (polychaete-dominated) and Stage II (amphipod-dominated) seres. Stage III seres tend to be maintained over periods of several years

Table 2.5-5.
Calculation of REMOTS Organism-Sediment Index Value

A. CHOOSE ONE VALUE:		
	Mean aRPD Depth	Index Value
	0.00 cm	0
	> 0 - 0.75 cm	1
	0.75 - 1.50 cm	2
	1.51 - 2.25 cm	3
	2.26 - 3.00 cm	4
	3.01 - 3.75 cm	5
	> 3.75 cm	6
B. CHOOSE ONE VALUE:		
	Successional Stage	Index Value
	Azoic	-4
	Stage I	1
	Stage I to II	2
	Stage II	3
	Stage II to III	4
	Stage III	5
	Stage I on III	5
	Stage II on III	5
C. CHOOSE ONE OR BOTH IF APPROPRIATE:		
	Chemical Parameters	Index Value
	Methane Present	-2
	No/Low Dissolved Oxygen**	-4
REMOTS ORGANISM-SEDIMENT INDEX =	Total of above subset indices (A+B+C)	
	RANGE: -10 - +11	

** Note: This is not based on a Winkler or polarigraphic electrode measurement. It is based on the imaged evidence of reduced, low reflectance (i.e., high oxygen demand) sediment at the sediment-water interface.

unless they are eliminated by increasing organic loading, extended periods of hypoxia, or burial by thick layers of dredged material. The recovery of Stage III seres following abatement of such events may take several years (Rhoads and Germano 1982). Stations that have low or moderate OSI values (< +6) are indicative of recently disturbed areas and tend to have greater temporal and spatial variation in benthic habitat quality than stations with higher OSI values (> +6).

2.5.4 Sediment Plan View Image Acquisition

Plan view (i.e., "downward-looking" or horizontal sediment surface plane) photographs of approximately 0.3 m^2 of the seafloor surface were obtained in conjunction with the REMOTS sediment-profile images at each station (Figure 2.5-1). The photographs were acquired with a PhotoSea 1000a 35 mm Underwater Camera System and a PhotoSea 1500s Strobe Light attached to the REMOTS sediment-profile camera frame. The plan view images were acquired immediately prior to the landing of the REMOTS sediment-profile camera frame on the seafloor, providing an undisturbed record of the surface sediments before penetration of the REMOTS sediment-profile prism. Once the camera frame was lifted above the sediments, the plan view camera system automatically cycled the film and recharges the strobe in preparation for the next image. In this manner, a corresponding plan view image was usually obtained for each REMOTS sediment-profile image acquired.

2.5.5 Sediment Plan View Image Analysis

The purpose of the plan view image analysis was to supplement the more detailed and comprehensive REMOTS characterization of the seafloor. Analysis of the plan view images included screening all the replicate images acquired at each station to select one representative image for analysis. Poor water clarity, lack of contrast or water shots taken prematurely due to the camera system trigger sensitivity (sediment surface not within the focal length of the system when activated) eliminated some of the images from further consideration.

The plan view image analysis consisted of qualitative descriptions of key sediment characteristics (e.g., sediment type, bedforms and biological features) based on careful scrutiny of each chosen replicate image. Sediment descriptions were based on visual observations and therefore only the obvious presence of boulders, cobble, rock, gravel, sand and/or fines (clay and silt) were noted. Bedforms were described as being either rippled (i.e., presence of sand waves) or smooth (i.e., absence or very little evidence of sand waves) to provide an indication of physical processes (i.e., currents). Any evidence of epifaunal or infaunal organisms (i.e., fish, starfish, tubes, burrow openings, fecal mounds etc.) was also recorded.

2.6 Benthic Grab Sampling

2.6.1 Benthic Grab Sample Collection

A single sediment grab sample was obtained for benthic community analysis at 5 of the 50 REMOTS stations (10%) over the 1993 Dioxin Mound (stations A5, A9, A19, A23 and B8), as well as at 3 of the 10 stations (33%) in the South Reference Area (stations S4, S8 and S14; Figure 2.5-1). Grab samples were collected at each station using a stainless steel, 0.04 m^2 Young-modified van Veen grab sampler having a maximum penetration depth of 12 cm. Upon arrival at the target station, the grab sampler was set in an open position and lowered to the seafloor on a stainless steel winch wire. Upon reaching the bottom, the device was retrieved, causing the bucket to close and retain a surface sediment sample. The grab sampler was raised on the winch wire and placed on a stand secured to the deck of the survey vessel.

After retrieving the grab sampler, the sediment sample was determined to be acceptable or not. An acceptable grab was characterized as having relatively level, intact sediment over the entire area of the grab, and generally a sediment depth at the center of at least 7 cm. Grabs showing disturbance of the sediment surface or those containing an insufficient volume of sediment were determined to be unacceptable and rejected, resulting in re-deployment of the sampler at the station until an acceptable sample was obtained. The time of collection and geographic position of the sample were recorded both in the field logbook and by the navigation system.

Immediately following retrieval, a small subsample of surface sediment was scooped out of each acceptable grab and placed in a plastic bag for subsequent grain size analysis. The remaining sediment in the grab was transferred to a sieve having a 0.5 mm mesh size. During the sieving process, the sieve was placed on a sieve table, and a gentle flow of water was washed over the sample. Extreme care was taken to ensure that no sample was lost over the side of the sieve while agitating or washing the sample. The organisms and material (e.g., shells, wood, rock fragments, etc.) retained on the screen were placed into a labeled 1-L wide-mouth plastic container. The sample was then preserved using a 6% buffered formalin solution with Rose Bengal added to stain the organisms. Once the cap was secured, the contents were mixed by inverting the container several times. All samples were delivered by overnight mail to Barry A. Vittor and Associates, Inc. (BVA) of Mobile, AL for detailed benthic analysis (sorting, enumeration and identification to lowest practicable identification level (LPIL).

2.6.2 Benthic Sample Processing

At the BVA laboratory, each benthic sample was sorted with a dissecting microscope, and the preserved specimens identified and counted. Individual organisms were removed from each sample and placed in vials, then labeled by major taxonomic group. Taxonomists with a specialization within each major taxonomic group proceeded to identify the preserved organisms to the LPIL. Quality Assurance and Control procedures (QA/QC) associated with the benthic taxonomic analyses at BVA are described in the Quality Assurance Project Plan (SAIC 2002a).

2.6.3 Benthic Data Analysis

The raw benthic community data received from the laboratory consisted of a standard species list showing the number of individuals of each taxon collected in the single grab sample at each station. Since the Van Veen grab sampled a 0.04 m^2 area of the bottom, the raw sample counts were multiplied by 25 to express abundance on a standard "per m^2" basis. Analysis of the benthic community data included both univariate and multivariate statistical approaches, as described in the following sections.

2.6.3.1 Univariate Statistics

A number of standard univariate statistics were used to summarize the benthic community data for the 1993 Dioxin Mound and the South Reference stations, including calculation of the average organism density (number of individuals per m^2) per station, average number of taxa, and the percentage breakdown of abundance by taxa. Additional analyses were performed to calculate species richness, diversity, and evenness index values for each station (sample), using the PRIMER (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory, UK (Clarke and Warwick 1994).

Species richness was determined using Margalef's index (d), which provides a measure of the number of species (S) present for a given number of individuals per m^2 (N) according to the following equation:

$$d = (S\text{-}1)/\log_e N$$

Diversity was calculated using the Shannon-Weiner (H') index:

$$H' = -\Sigma_i \, p_i \, (\log_e p_i),$$

where p_i is the proportion of the total count arising from the *ith* species.

Equitability, the evenness of the species distribution, was determined using Pielou's evenness index (J'):

$$J' = H' \text{ (observed)}/ \; H' \text{ max},$$

where H' max is the maximum possible diversity which would be achieved if all species were equally abundant = $\log_2$ (S). All three indices were determined using the DIVERSE routine within the PRIMER software package.

2.6.3.2 Multivariate Statistics

The univariate statistics described in the previous section each provide a measure of a single community attribute (e.g., species richness, diversity, evenness). In contrast, multivariate statistical techniques involve looking at the benthic community structure as a whole when trying to discern spatial patterns or when comparing among different samples (Clarke 1999). The term "benthic community structure" used herein refers to the concept of looking simultaneously at both the taxa that are present and their relative numbers when comparing different samples to each other.

Using the PRIMER software package, two independent but complimentary multivariate techniques were used to evaluate both the among-station and among-site patterns in overall benthic community structure: hierarchical clustering and non-metric multi-dimensional scaling (nMDS). Each of these techniques serves to classify the stations into groups having mutually similar benthic community structure. As explained in more detail below, the techniques differ in the type of graphic display produced.

Clustering and nMDS are non-parametric methods that do not require the data to be transformed to meet underlying statistical assumptions. However, transformations do play an important role in these techniques by defining the balance between contributions from common versus rarer species in the measure of similarity among samples. In the present analysis, a decision was made to apply a square root transformation to the species abundance data to down-weight the contribution of the numerically dominant taxa while increasing the contribution of the rarer and/or less abundant taxa in assessing the degree of similarity among samples.

Prior to performing the clustering, the abundance values were square-root transformed, and a matrix was then constructed consisting of Bray-Curtis similarity index values (Bray and Curtis 1957) calculated between each possible pair of stations (i.e., pairwise comparisons). Hierarchical agglomerative clustering with group-average linking was then performed on this similarity matrix based on the square-root transformed abundance data (Clarke 1993). Representation of the results was by means of a tree diagram or dendrogram, with the x-axis representing the full set of samples and the y-axis representing the Bray-Curtis similarity level at which two samples or groups are considered to have fused.

Non-metric multi-dimensional scaling (nMDS) attempts to provide an ordination, or "map," of the stations such that distances between stations on the map reflect corresponding similarities or dissimilarities in community structure. Stations that fall in close proximity to one another on an nMDS plot have similar community structure, while those that are farther apart have dissimilar structure (e.g., few taxa in common or the same taxa at different levels of abundance). Like the cluster analysis, nMDS ordination (Kruskal and Wish 1978) was performed on the matrix of Bray-Curtis similarity index values derived from the square root transformed abundance data (Clarke and Green 1988; Clarke 1993). The two-dimensional nMDS plot provides a simple and compelling visual representation of the “closeness” of the benthic community structure (i.e., species composition and abundance) between any two samples or sample groups.

The ANOSIM (Analysis of Similarities) randomisation test within the PRIMER software package was used to test for statistical differences in overall benthic community structure between the 1993 Dioxin Mound stations and the South Reference Area stations. The ANOSIM procedure is analogous to standard parametric analysis of variance (ANOVA) but is based on a non-parametric permutation procedure applied to the Bray-Curtis similarity matrix underlying the ordination of samples (Clarke and Green 1988; Clarke 1993). This test involves calculation of a test statistic, R, which reflects the observed differences in Bray-Curtis similarities between sites, contrasted with differences among replicates within sites.

The ANOSIM procedure was used to provide a formal test of the null hypothesis of “no significant difference in overall benthic community structure between the 1993 Dioxin Mound and the South Reference Area.” The R-statistic serves to indicate the magnitude of the difference between the sites being tested and can range from 0 to 1. In general, $R>0.75$ indicates strong separation (i.e., a big difference in overall benthic community structure), $0.75 > R > 0.25$ indicates varying degrees of overlap but generally different community structure, and $R<0.25$ indicates little separation between sites. The ANOSIM procedure also calculates a significance level that corresponds to the alpha level (probability of Type I error) in traditional ANOVA.

Following the ANOSIM test for among/between site differences, the program SIMPER in the PRIMER package was used to identify the taxa that were the "key discriminators" in contributing to differences in benthic community structure between the two sites.

2.7 Sediment Coring Survey

2.7.1 Sampling Design and Field Methods

Station locations for the vibracoring survey mirrored those historically sampled. Stations were initially selected to optimize sampling of the placed dredged and cap material during previous surveys of the 1993 Dioxin Mound. Figure 2.7-1 shows the location of the 14 stations sampled during the coring survey, in relation to the 2002 bathymetric survey results.

The sediment coring survey was conducted aboard the NYD's M/V *Gelberman* from August 4 to 8, 2002. One sediment core was collected at each of the 14 stations shown in Figure 2.7-1. When appropriate the vessel utilized a 2-point anchoring system for core collection. Cores were cut on the survey vessel into approximately 80 cm lengths, such that the sand cap-dredged material interface remained undisturbed. Cores were labeled and stored vertically in a refrigerated unit until processed at the NYD's Caven Point laboratory facility by SAIC technicians.

An Ocean Surveys, Inc. Model 1500 vibracorer, with an internal diameter of 3.5 inches, was used to acquire the sediment core samples. This device was selected because of its demonstrated ability to acquire sediment core samples of at least 2 m in length on sand-capped mounds within the HARS. Immediately following retrieval of the vibracoring device at each station, the core liner was removed from the barrel and carefully capped and taped to prevent loss of sediment and/or water. The core was then labeled with a unique station identifier that included the month and year of the survey, the station name, number of core sections and unique identifying section labels. The cores were stored vertically in a refrigerated unit aboard the survey vessel. Cores remained refrigerated aboard the vessel and throughout the survey and analysis procedures at NYD's Caven Point facility.

2.7.2 Core Processing

The cores were transported vertically to a refrigerated unit at the NYD's Caven Point Facility where the laboratory was utilized for processing. In the laboratory, all 14 cores were split, visually described, digitally photographed, and sampled for geotechnical and sediment chemical analyses. All subsamples were kept refrigerated until shipped to the appropriate subcontracting laboratory in coolers with wet ice. Samples for sediment chemical analysis were shipped to Pace Analytical, St. Paul, Minnesota, where samples were analyzed for PCDD/PCDFs (dioxin and furans) and TOC. Geotechnical analyses included water content, bulk density, grain size, specific gravity and shear strength. SAIC technicians conducted the shear strength analysis on site while the remainder of the geotechnical analyses were conducted on samples shipped to Applied Marine Science in League City, Texas.

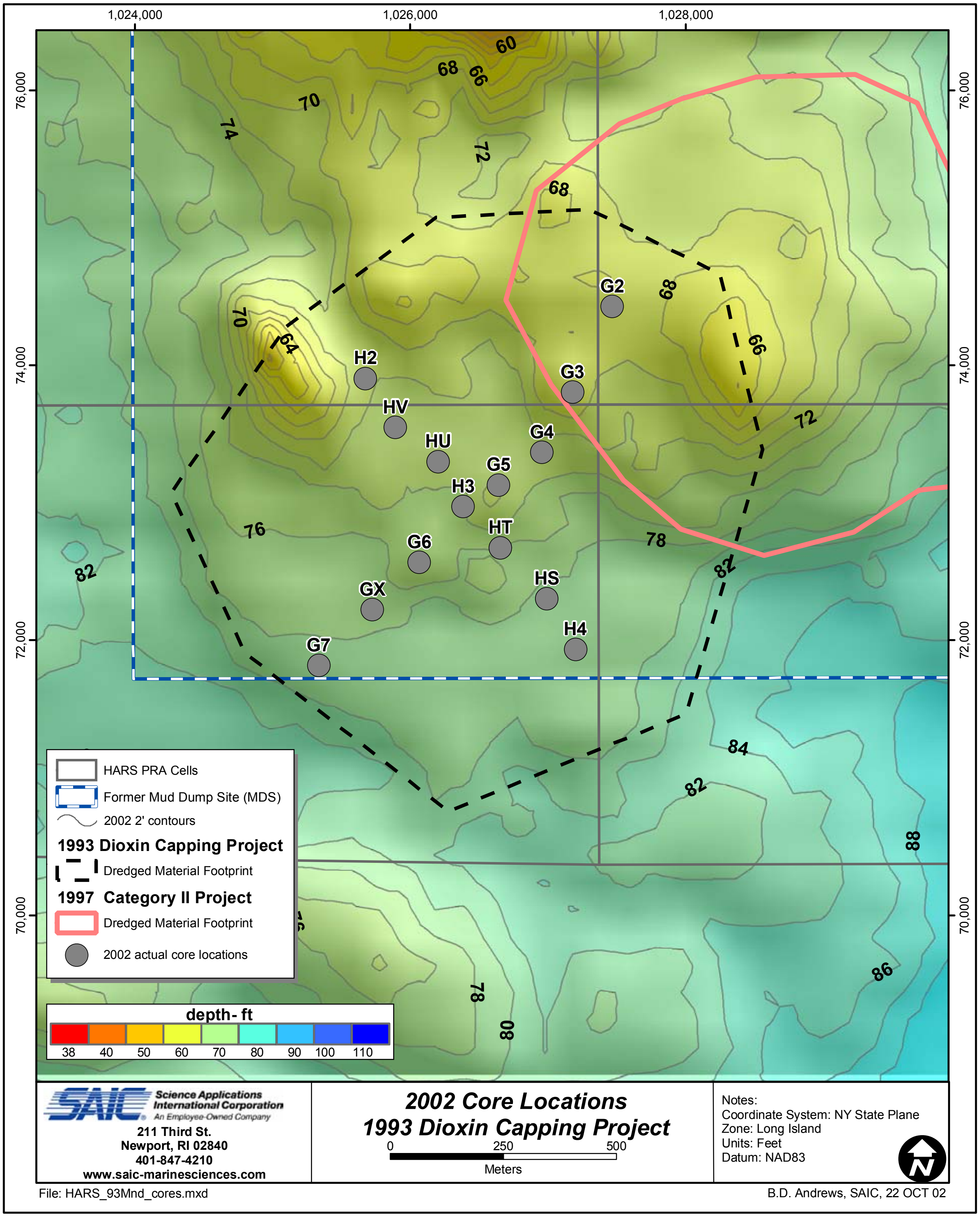


Figure 2.7-1. Vibracore station locations for the 2002 survey over the 1993 Dioxin Mound

2.7.2.1 Core Splitting

Each core liner was scored horizontally using an SAIC designed core splitter. The core splitter is designed to score the exterior of the core liner, leaving a thin layer of Lexane liner such that the bits cut the liner and not the sediment. The thin layer of remaining liner was then cut using a pre-cleaned utility knife, and a thin wire was used to split the sediment axially into two halves. The wire is drawn from the top of the core to the bottom to avoid potential chemical contamination of the cleaner cap sediments by the underlying project material. One half-section of the core was used for detailed visual description, digital imaging, and sediment chemical analysis sampling. The remaining core half was processed for geotechnical analyses.

2.7.2.2 Core Descriptions and Imaging

After splitting, each core was carefully examined and described in detail by SAIC personnel. Visual descriptions follow a standard SAIC modification of ASTM (American Standard Test Method) D2488 for the Description and Identification of Soils (Visual-Manual Procedure). Core descriptions were entered directly into an SAIC database and tracking system. The tracking program generated the Chain-of-Custody forms sent to the laboratories along with the subsamples. The split cores were photographed with an Olympus D500L digital camera mounted on a tripod equipped with lights. The focal distance was kept constant to easily mosaic (join) the individual images to form a continuous view of the core. The descriptions, images and sample intervals were combined within the database and used to generate a log for each core; these core logs are presented in Appendix C-1 of this report.

2.7.2.3 Core Sampling

Sediment cores were sampled for both geotechnical and chemical analyses beginning on August 7, 2002. Table 2.7-1 summarizes the type of analyses performed on each core retained by SAIC. All of the 14 cores were visually described and imaged. Geotechnical analyses included measurements of water content, bulk density, grain size (sieve and hydrometer), and specific gravity. Additionally, one shear strength measurement was conducted per core. Chemical analyses of the sediment samples included measurements of PCDD/PCDFs (i.e., dioxins and furans), TOC, and percent moisture.

The sampling plan was designed around the visual interface between the sand cap material and underlying dredged material. Samples for grain size analysis were collected from 10 cm above (sieve only) and 10 cm below (with hydrometer) this interface. Samples for bulk density, water content, and specific gravity analyses were also collected at these two horizons. Shear strength analysis was conducted 10 cm below the interface in each core. Additional bulk density and water content samples were collected at 10 cm intervals from the interface such that a total of three samples were collected from the cap while a maximum of seven samples were collected from the underlying dredged material. In some cases the core did not capture a sufficient volume of sediment to collect all of the subsamples below the interface. In these cases, samples were collected over the entire length of the core.

Table 2.7-1.
1993 Dioxin Mound Core Analysis Summary

Core ID	Visual Description	Geotechnical Analysis	Chemical Analysis	Total Core Length (cm)	Latitude (N)	Longitude (W)
G2	X	X	X	286	40.3709	73.8449
G3	X	X	X	280	40.3692	73.8459
G4	X	X		224	40.3679	73.8468
G5	X	X		220	40.3673	73.8479
G6	X	X		300	40.3658	73.8499
G7	X	X		236	40.3637	73.8526
GX	X	X		276	40.3648	73.8512
H2	X	X		280	40.3694	73.8513
H3	X	X	X	243	40.3669	73.8488
H4	X	X	X	272	40.3640	73.8459
HS	X	X		234	40.3650	73.8466
HT	X	X	X	265	40.3661	73.8478
HU	X	X		192	40.3678	73.8495
HV	X	X	X	238	40.3685	73.8506

The core subsamples were collected from discrete 6-cm intervals at specific core depths based on the cap material and dredged material interface. Each subsample was identified by the core name and the depth at which the sample was collected, or centimeters down core. Additionally, subsamples collected from the cap material (above the interface) were identified with a (+) while samples from the dredged material unit or below the interface were identified with a (-) symbol preceding the depth at which the sample was collected. For example, sample HV+100 was collected from Core HV, above the interface (+), and from a depth of 100 cm. Likewise, sample HV-160 was collected from the same core, below the interface (-) at a depth of 160 cm.

2.7.3 Laboratory Analysis of Subsamples

2.7.3.1 Geotechnical Analyses

Grain Size

Grain size distributions of the sediment samples were determined in accordance with ASTM Method D422. Sieve sizes for sand fraction analyses included US standard sieve sizes 10, 20, 40, 60, 100, and 200, to provide coarse (1–0 phi), medium (2–1 phi), fine (3–2 phi), and very fine (4–3 phi) sand fractions, respectively. Clay and silt fractions were measured using a hydrometer (ASTM Method D422). Size classifications were based on the Wentworth (1922) scale (Table 2.5-3). Hydrometer analysis was only conducted on samples originating below the cap/dredged material interface.

Bulk Density and Water Content

Assuming no void space due to air, the wet mass of sediment divided by the volume yields the bulk density. Bulk density for the cores was determined by pushing a cylinder of known volume into the sediment surface of the core half, leveling off each end, and then weighing it. Water content is defined as the weight of water divided by the dry weight of the sample, and is reported as a percentage. Mathematically, it is computed using the following formula:

Water Content = ((wet weight - dry weight)/ dry weight)X 100

It should be noted that in geotechnical analysis, this formulation may indicate water content values greater than 100%. For this analysis, the wet samples were weighed, dried at 110°C for 24 hours, and then reweighed according to the procedures outlined in ASTM Method D 2216. Because these samples were from the marine environment, when dried, the salt from the water was left behind, resulting in a higher dry weight (weight of solids) and consequently lower water content. Since geotechnical properties are generally based on sediments saturated with fresh water, the water contents obtained via the above formula were then normalized by an assumed salt content of 32 ppt (roughly the salinity of bottom water at the HARS), following ASTM procedures.

Specific Gravity

Specific gravity is defined as the ratio of the mass of a unit volume of material to the same volume of gas-free distilled water at a stated temperature (ASTM Method D 854), and is represented by the following formula:

G at $T_b = M_o/[M_o + (M_a - M_b)]$

where:
G = specific gravity
M_o = mass of sample of oven-dry soil, g_1
M_a = mass of pycnometer filled with water at temperature T_b, g_1
M_b = mass of pycnometer filled with water and soil at temperature T_b, g_1
T_b = temperature of the contents of the pycnometer when mass M_b was determined, ºC.

Specific gravity was measured within the dredged material layer of each of the cores, using ASTM D 854, Method A (procedure for oven dried test specimens).

Shear Strength

A laboratory vane was used to make direct measurements of the shear strength of the sediment within the cores. Vane size is determined by the softness of the material to be measured; the laboratory vane used for this material measured 12.7 X 12.7 mm. Shear strength measurements were conducted on one half of the core. A motorized vane was used to ensure consistent torque and more accurate results. Shear strength, a calculated value based on degree of spring deflection (inner) and degree of rotation of the vane (outer). Softer material requires a larger vane and soft spring, while firmer material requires a stiffer spring and smaller vane. The SAIC procedure for vane shear testing is based on ASTM D4648.

$S = M/K$ Where: S = Shear strength in kN/m^2
K = constant for the vane size used
M = Torque in N m

Vane 12.7 X 12.7 mm; $K = 0.004290$
Calculating M: $M = C_s\theta_f$
Where: M = is the applied torque (N mm)
C_s = is the calibration factor (N mm/degree) for the spring being used obtained from calibration data.

θ_f = is the reading indicated by the pointer on the inner scale after each test gives the relative angular deflection of the ends of the spring failure.

2.7.3.2 Sediment Chemical Analysis

Sample Collection

Sediment samples for chemical analysis were extracted from the split core at 10 and 30 cm above and below the visual cap/dredged material boundary. Coring stations that contained historical sediment chemistry data from previous surveys were selected for chemical analysis during the 2002 survey. To obtain a sufficient quantity of sediment for testing PCDD/PCDFs and TOC, samples were collected from an approximate 6-cm thick section of the core encompassing the desired sample point. Sample locations within each core are included in the core description logs in Appendix C-1.

Samples from the sand cap were removed from the core first to decrease the possibility of contamination. To further minimize contamination, only material not in contact with the core liner was sampled. Stainless steel spatulas and mixing bowls were used to remove and homogenize the sediment. Samples were placed into 125-ml precleaned glass jars. PCDD/PCDF samples were placed in amber containers due to the photosensitive nature of these compounds. TOC samples were placed in similar containers. Sampling equipment was scrubbed with Alconox ®, rinsed with distilled water, methanol and nitric acid between each sample. Samples were kept refrigerated or on ice (approximately 4° C) in coolers and in the dark, and were shipped by overnight airfreight to Pace Analytical Services, Inc. located in St. Paul, MN.

Total Organic Carbon (TOC)

TOC analyses were performed using EPA's SW-846 Method 9060 (USEPA 1997a). In this method, organic carbon is measured using a carbonaceous analyzer that converts the organic carbon in a sample to carbon dioxide (CO_2) by either catalytic combustion or wet chemical oxidation. The CO_2 formed is then either measured directly by an infrared detector or converted to methane (CH4) and measured by a flame ionization detector. The amount of CO_2 or CH4 in a sample is directly proportional to the concentration of carbonaceous material in the sample. Results in this report are expressed on a dry weight basis.

PCDD/PCDF Analyses

This section describes the methods used for sample preparation, extraction, and analysis of PCDDs/PCDFs, including QC samples. A detailed discussion of QA/QC procedures were provided in the Quality Assurance Project Plan (SAIC 2002b).

Results of QA/QC analyses are given in Section 3.0. Samples were analyzed by Pace Analytical, Inc. using EPA Method 8290 (USEPA 1997b), with modifications, such as the levels of the internal standards, recovery standards, and native spiking materials, at the levels described in EPA Method 1613 (USEPA 1994). Following extraction, sample extracts were analyzed for the following PCDDs/PCDFs using combined capillary column gas chromatography/high resolution mass spectrometry (HRGC/HRMS):

Dioxins (PCDDs):	Furans (PCDFs):
2,3,7,8-TCDD (Dioxin)	2,3,7,8-TCDF (Furan)
1,2,3,7,8-PeCDD	1,2,3,7,8-PeCDF
1,2,3,6,7,8-HxCDD	2,3,4,7,8-PeCDF
1,2,3,4,7,8-HxCDD	1,2,3,6,7,8-HxCDF
1,2,3,6,7,9-HxCDD	1,2,3,6,7,9-HxCDF
total 2,3,7,8-HpCDD	1,2,3,4,7,8-HxCDF
OCDD	2,3,4,6,7,8-HxCDF
	1,2,3,4,6,7,8-HpCDF
	1,2,3,4,,7,8,9-HpCDF
	OCDF

The 17 PCDDs/PCDFs listed above are the compounds analyzed in Method 8290. Fourteen of these compounds are called "2,3,7,8-substituted PCDDs/PCDFs" and are the PCDDs/PCDFs believed to pose the greatest risks to human health and the environment based on structure activity relationships. The requested laboratory detection limit was 1 pptr for the tetra compounds, 5 pptr for the penta, hexa, and hepta compounds, and 10 pptr for the octa compounds.

Statistical Analysis

Descriptive statistics calculated for the geotechnical and sediment chemistry data included average, standard deviation, coefficient of variation, minimum, and maximum for each of the physical and chemical properties reported, grouped by unit (e.g., cap material and dredged material). For calculation of geochemical statistics, where concentrations were below detectable limits, one-half the Limit of Detection (LOD) was used (Clarke 1994). The coefficient of variation (CV) is a measure of the amount of variability within a set of data. It is calculated using the following formula:

Coefficient of Variation (CV) = (standard deviation/average)X100

2,3,7,8–TCDD Toxic Equivalent Concentrations (TECs)

Method 8290 requires the calculation of the 2,3,7,8–TCDD Toxic Equivalent Concentration (TEC) to aid in the assessment of risks associated with exposure to these compounds. A 2,3,7,8–TCDD Toxicity Equivalence Factor (TEF; Safe 1990) is assigned to each of the 2,3,7,8–substituted PCDDs/PCDFs (Table 2.7-2). A TEF relates the toxicity of that congener to an equivalent concentration of the most toxic congener, 2,3,7,8–TCDD or dioxin. TEFs were defined by a 1989 international scheme (I-TEFs/89, NATO-CCMS 1988a, 1988b) and have been adopted by EPA (USEPA 1989). TEFs are different for each congener. The concentrations of congeners detected in environmental samples are multiplied by their respective TEF, and the products are summed over all congeners, yielding a concentration with the same toxicity as an equivalent amount of 2,3,7,8–TCDD. This concentration is variously referred to as a TCDD Equivalent (TCDD-EQ), a TEQ (Toxic Equivalent), and, in this report, a Toxic Equivalent Concentration (TEC), expressed in units of ng/kg or pptr. The TECs were calculated using a value of one-half the LOD for values below detection (Clarke 1994; McFarland et al. 1994).

Table 2.7-2.
2,3,7,8–TCDD Toxicity Equivalence Factors (TEFs) for
Polychlorinated Dibenzodioxins (Dioxin) and Dibenzofurans (Furan)

Number	Compounds	TEF (pptr)
	Dioxin Compounds	
1	2,3,7,8-TCDD	1.000
2	1,2,3,7,8-PeCDD	0.500
3	1,2,3,6,7,8-HxCDD	0.100
4	1,2,3,7,8,9-HxCDD	0.100
5	1,2,3,4,7,8-HxCDD	0.100
6	1,2,3,4,6,7,8-HpCDD	0.010
7	OCDD	0.001
8	*Total -TCDD	0
9	*Total -PeCDD	0
10	*Total -HxCDD	0
11	*Total -HpCDD	0
	Furan Compounds	
12	2,3,7,8-TCDF	0.100
13	1,2,3,7,8-PeCDF	0.050
14	2,3,4,7,8-PeCDF	0.500
15	1,2,3,6,7,8-HxCDF	0.100
16	1,2,3,7,8,9-HxCDF	0.100
17	1,2,3,4,7,8-HxCDF	0.100
18	2,3,4,6,7,8-HxCDF	0.100
19	1,2,3,4,6,7,8-HpCDF	0.010
20	1,2,3,4,7,8,9-HpCDF	0.010
21	OCDF	0.001
22	*Total -TCDF	0
23	*Total -PeCDF	0
24	*Total -HxCDF	0
25	*Total -HpCDF	0

*Excluding the 2,3,7,8-substituted congeners.
Reference: 1989 ITEFs

3.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Data quality is typically assessed in relation to specified criteria for precision, accuracy, representativeness, comparability, and completeness (PARCC). Analytical precision is expressed as the percent difference between results of replicate samples (Relative Percent Difference [RPD] or Coefficient of Variation [CV]). Analytical accuracy is evaluated quantitatively as the percent recovery of a spiked standard compound added at a known concentration to the sample before analysis. When spiked duplicates are run, the results can be expressed as an RPD to evaluate precision of the analysis of the spiked compounds. By inference, the precision of analysis of other related compounds should be similar. Laboratory accuracy also is evaluated qualitatively by evaluating the laboratory QC information on sample holding times, method blank results, tuning and mass calibration, recovery of internal standards, laboratory quality control samples, and initial and continuing calibration checks. The following section defines the various QA/QC requirements and summarizes the data quality objectives for this project.

3.1 Geotechnical Quality Control Data

All analyses were completed in accordance with the project objectives, and data were fully documented. Geotechnical data were received from Applied Marine Science in both hard copy and electronic formats. All geotechnical analyses were conducted using standard ASTM methods. As part of these methods, associated QA/QC procedures were followed by AMS. All of the samples were within the acceptable QC limits of <25% RPD. Other QC procedures in the analysis of geotechnical data include triplicate analysis of water content and grain size. These tests were preformed in the sand cap material of sample H4+182, and within the dredged material sediments of sample H3-172.

The CV was used to evaluate the precision of these data. Water content triplicates had a CV of 0.6% and 0.7% for the sand cap and dredged material layers, respectively (Table 3.1-1). For the major (≥20%) grain size components CVs ranged from 0 (fine sand in the cap) to 3.9% (silt in the DM). When the CV% is calculated for small numbers, particularly with a large range, the values tend to be skewed towards the high end. For this reason, the CV was calculated only for grain sizes comprising ≥20% of the sample. Overall, the CVs for these triplicate analyses indicate very good precision and are all acceptable.

3.2 Sediment Chemistry Quality Control Data

3.2.1 Sample Tracking Procedures and Holding Times

SAIC standard operating procedures for sample tracking and custody were followed. In preparation for the field survey, a checklist of all samples to be collected was prepared. Sample containers were pre-cleaned, amber glass jars with Teflon-lined lids (3,000 series), and the labels were preprinted in indelible ink. Individual subsample identifiers were added to all labels in indelible ink in the field laboratory. After the subsamples were collected, the jars were sealed with waterproof tape. Label information included SAIC contact information, survey name, sample station, sample interval, type of analysis and the subcontracting laboratory contact

Table 3.1-1.
Results of Triplicate Analysis of Sand Cap and Dredged Material Samples to Assess Analytical Precision

	Gravel >#4 (%)	**Coarse Sand #10 (%)**	**Medium Sand #20-#40 (%)**	**Fine Sand #60-#200 (%)**	**Silt 0.074-0.005 mm (%)**	**Clay <0.005 mm (%)**	**Passing No. 200 <0.074 mm (%)**	**Water Content* (%)**
Sand Cap Material Core H4+182	0.34	1.08	13.72	84.60	-	-	0.26	97
	0.36	1.04	13.77	84.51	-	-	0.32	98
	0.35	0.98	13.75	84.65	-	-	0.27	98
Average	0.35	1.03	13.75	84.59	-	-	0.28	97.67
Standard Deviation	0.01	0.05	0.03	0.07	-	-	0.03	0.58
CV (%)	**	**	**	**0.08**	**-**	**-**	**	**0.59**
Dredged Material Core H3-172	0.00	0.09	0.28	1.79	34.84	63.00	-	86
	0.00	0.10	0.28	1.89	35.24	62.50	-	87
	0.00	0.08	0.27	1.66	37.48	60.50	-	87
Average	0.00	0.09	0.28	1.78	35.85	62.00	-	86.67
Standard Deviation	0.00	0.01	0.01	0.12	1.42	1.32	-	0.58
CV (%)	**	**	**	**	**3.97**	**2.13**	**-**	**0.67**

CV= Coefficient of Variation (see Section X.x)

* Water Content Corrected for 35 ppt salinity

**CVs were only claculated for major grain size components (>20%)

information. All sediment chemistry samples were stored at 0–4° C. Chain-of-custody records were maintained and generated from the SAIC tracking database for all samples.

The sediment samples were collected from August 7–10, 2002. They were stored under refrigeration and in the dark until they could be shipped to the laboratory on August 9, 2002. The laboratory received the samples on August 10, 2002. Extraction of sediment samples was undertaken from August 22 to September 16, 2002 and the samples were analyzed from August 29 to September 24, 2002. The recommended maximum holding time for dioxin/furan samples is 30 days from sample collection to extraction, and 45 days from collection to analysis, as specified in Method 8290 (USEPA 1997b). The more recent Method 1613 states, however, that there are no demonstrated maximum holding times associated with PCDDs/PCDFs in aqueous, solid, semi-solid, tissues, or other sample matrixes, as well as extracts, and samples may be stored up to one year (USEPA 1994). Samples were held for a maximum of 40 days between collection and extraction and 48 days between collection and analysis. These samples were stored for less than the one-year recommendation of Method 1613 and the data, therefore, are considered valid with respect to sample holding time requirements.

3.2.2 Method Blanks

A laboratory method blank was prepared and analyzed with each sample batch as part of the routine laboratory quality control procedures. One blank (2101) contained a trace amount of OCDD. This level was below the calibration range of the method. Three samples associated with this blank contained OCDD at a similar level to that noted in the blank. The affected samples were flagged in the data summary sheets. In general, levels less than ten times the background are not considered statistically different from the background. All of the blanks were considered acceptable.

3.2.3 Assessment of Analytical Accuracy and Precision

Laboratory spike samples were prepared with each sample batch by extracting clean sand that had been fortified with native standards. Recoveries of spiked native compounds must fall within the range of 70 to 130% as defined by the laboratory standard operating procedure. The recoveries of the analytes from the spiked samples ranged from 80 to 116% with relative percent difference (RPD) of 0 to 17%, indicating acceptable accuracy. The OCDD in Spike Dup 2060 was recovered at an elevated level, outside of the target range and was flagged on the summary sheet; this also resulted in an elevated RPD for this analyte.

Analytical precision is expressed as the RPD between two results or the CV between three or more results. Two types of replicate samples were examined for precision analysis: laboratory spike samples, and three samples that were homogenized by the laboratory and then divided into triplicate subsamples. The triplicates were analyzed independently. The closer the numerical values of the measurements are to each other, the lower the RPD or CV. Low RPD or CV values indicate a high degree of analytical precision. The RPD between two sample results was calculated using the following equation:

RPD = (sample result - duplicate result)/(sample result + duplicate result)/2X 100

The CV values for the laboratory triplicates should equal 25% or less (USEPA 1997b). The CV for the laboratory spike samples ranged from 7.6 to 23.6%, indicating acceptable precision.

Three samples (HV+100, 97Q+60, and 97R+122) were each split into three aliquots to be analyzed as triplicates. The majority of the isotopically labeled PCDDs/PCDFs fell below the detectable limit, thus precision calculations could not be made for these samples as neither dioxin or furan was detected (Table 3.2-2). Laboratory precision was found to be acceptable in that none of the samples indicated a detectable level of dioxin or furan.

3.2.4 2,3,7,8–TCDF Confirmation

Confirmation of 2,3,7,8–TCDF was performed on all samples having detected concentrations of this isomer. On the initial DB-5 capillary gas chromatographic column, other isomers can coelute with furan. Historically, problems have been associated with the separation of 2,3,7,8– TCDF and 2,3,4,7–TCDF. Therefore, these samples with concentrations over 1 pptr were re-run on a second, DB-DIOXIN column in order to confirm the presence of the 2,3,7,8–TCDF isomer. All of the samples analyzed were flagged with the detection limit based on signal-to-noise measurement and were verified by confirmation analysis.

3.2.5 Instrument Performance

Continuing calibration checks of the instrument must show a response deviation within 25% RPD for the 17 PCDD/PCDF compounds of interest and within ±35% RPD for the nine isotopically labeled PCDD/PCDF internal standards (USEPA 1997b). Daily instrument calibration checks indicated response factor deviations within these specified limits.

3.2.6 Total Organic Carbon (TOC)

A total of 40 sediment samples were analyzed for TOC according to EPA Method SW846 9060. Analyses were carried out between August 30 and September 3, 2002. Triplicates were taken from three sediment core samples, 97D-236, 97R-162, and H3-192 yielding CVs of 11%, 19% and 0%, respectively (Table 3.2-3). Analyses of TOC are typically subject to a high degree of variation. These CV values generally indicate acceptable precision.

3.2.7 Representativeness, Completeness, and Comparability

Sample representativeness was ensured during the sampling survey by collecting a sufficient number of sediment samples from the cap (12 samples) and dredged material (12 samples) portions of the cores. All samples were collected in a uniform manner and are considered to be representative of the area sampled (see Methods).

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. Comparability is based in large part on the other PARCC parameters because precision and accuracy must be known to compare one data set with another. To optimize comparability, sampling stations and sampling procedures used in the August 2002 survey were consistent with those employed in previous surveys of the HARS in which sediment chemistry samples were collected. Analytical methods and protocols were also the same for this

Table 3.2-2.
Results of Triplicate Analysis for Dioxin and Furan
in Samples HV+100, 97Q+60 and 97R+122.
Average concentrations are in pptr.

Compound Name	HV+100 Average	HV+100 STDEV	HV+100 CV%	97Q+60 Average	97Q+60 STDEV	97Q+60 CV%	97R+122 Average	97R+122 STDEV	97R+122 CV%
2,3,7,8-TCDF (Furan)	0.11	0.02	17	0.10	0.00	0	0.10	0.00	3
2,3,7,8-TCDD (Dioxin)	0.14	0.03	24	0.10	0.01	6	0.10	0.00	3
1,2,3,7,8-PeCDF	0.69	0.35	51	0.49	0.00	1	0.49	0.01	2
2,3,4,7,8-PeCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,7,8-PeCDD	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,4,7,8-HxCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,6,7,8-HxCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
2,3,4,6,7,8-HxCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,7,8,9-HxCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,4,7,8-HxCDD	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,6,7,8-HxCDD	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,7,8,9-HxCDD	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,4,6,7,8-HpCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,4,7,8,9-HpCDF	0.49	0.00	1	0.49	0.00	1	0.49	0.01	2
1,2,3,4,6,7,8-HpCDD	0.49	0.00	1	1.76	2.20	125	1.05	0.99	94
OCDF	0.97	0.03	3	3.33	4.04	121	1.83	1.53	83
OCDD	8.63	2.37	27	25.80	29.71	115	11.60	11.67	101

Table 3.2-3.
Results of Triplicate Analysis for Total Organic Carbon

Sample ID	Results (mg/kg)	Sample ID	Results (mg/kg)	Sample ID	Results (mg/kg)
H3-192	16000	97D-236	1600	97R-162	22000
H3-192 RUN 2	16000	97D-236 RUN 2	1300	97R-162 RUN 2	19000
H3-192 RUN 3	16000	97D-236 RUN 3	1400	97R-162 RUN 3	15000
Average	**16000**	**Average**	**1433**	**Average**	**18667**
STDEV	**0**	**STDEV**	**153**	**STDEV**	**3512**
CV%	**0**	**CV%**	**11**	**CV%**	**19**

and past surveys, and the same laboratory (Pace Analytical, Inc., formerly known as Maxim Technologies, Inc.) performed the analyses for all surveys.

For data to be considered complete, all samples must have been collected at all sampling areas specified in the original sampling plan, analyzed in full, and the values of each analysis reported. Sediment samples were collected from the specified intervals above and below the cap/dredged material interface, and all samples were analyzed. No samples were damaged during shipment. One hundred percent completeness was reported for the sample results.

4.0 RESULTS

4.1 Bathymetric Results

As addressed in detail in the companion report (SAIC 2003), the data quality review of the 2002 bathymetric survey results showed strong and consistent agreement throughout the entire HARS survey area. The main portion of the bathymetric survey over both the 1993 and 1997 mound areas was completed from 16 to 20 August 2002 and entailed a series of east-west survey lanes spaced at 100-foot intervals. Based on the gridded surface models created from the 2002 bathymetric survey, the 1993 Dioxin Mound represented a relatively subtle feature on the seafloor, gently sloping from depths of around 68 ft along the northern edge to 80 ft along the southern edge (Figure 4.1-1). The most significant topographic feature within the 1993 Dioxin Mound was a prominent circular feature along the northwest edge that rose up steeply to a minimum depth of around 56 ft from surrounding depths of 70 ft (Figure 4.1-1).

4.1.1 Depth Difference Results

The bathymetric depth difference grid computed between the October 1996 and the September 2002 surveys showed a significant area of accumulation in the northeast corner of the mound (Figure 4.1-2). This area of accumulation coincided well with the footprint of the 1997 Mound and was undoubtedly a result of the deposition of large quantities (2.4 million cu yds) of sand in this area during the 1997 Category II capping project between August 1997 and February 1998. In this area of high deposition, a maximum difference of 12.1 ft was detected.

To better analyze depth difference change in those areas that should not have been as impacted by the 1997 capping project, a depth difference grid was also generated excluding the northeast portion of the 1993 Dioxin Mound that fell within the 1997 Mound footprint (Figure 4.1-3). This grid indicated that there was still an overall trend of deposition (averaging about 1.3 ft throughout the grid), though at a much smaller magnitude than in the northeast quadrant. This may be a valid result, indicating that moderate deposition also occurred in other areas of the 1993 Dioxin Mound during the 1997 capping project. It is also possible that a slight bias in one (or both) of the surveys may have caused this consistent difference.

Because of the minor variability (due to sea action, vessel draft, tidal change, speed of sound differences, etc) and resolution limits associated with any bathymetric survey data, a certain degree of difference should be expected when comparing any two bathymetric survey data sets. If the surveys were conducted properly over the identical seafloor, then the differences should be randomly scattered and average out to around zero. If the trend of the differences was skewed in either a positive or a negative direction, then that would indicate that either the seafloor had changed or that one of the surveys had a bias that affected the data.

Because the 2002 bathymetric survey covered a large spatial area and the overall data consistency was strong throughout, it seemed more likely that a slight negative bias in the 1996 dataset may have caused the consistent offset evident in the depth difference grid (assuming uniform deposition was unlikely throughout the mound). If a uniform offset of –1.0 ft is applied to the 1996 dataset, then the depth difference results were more consistent with the types of

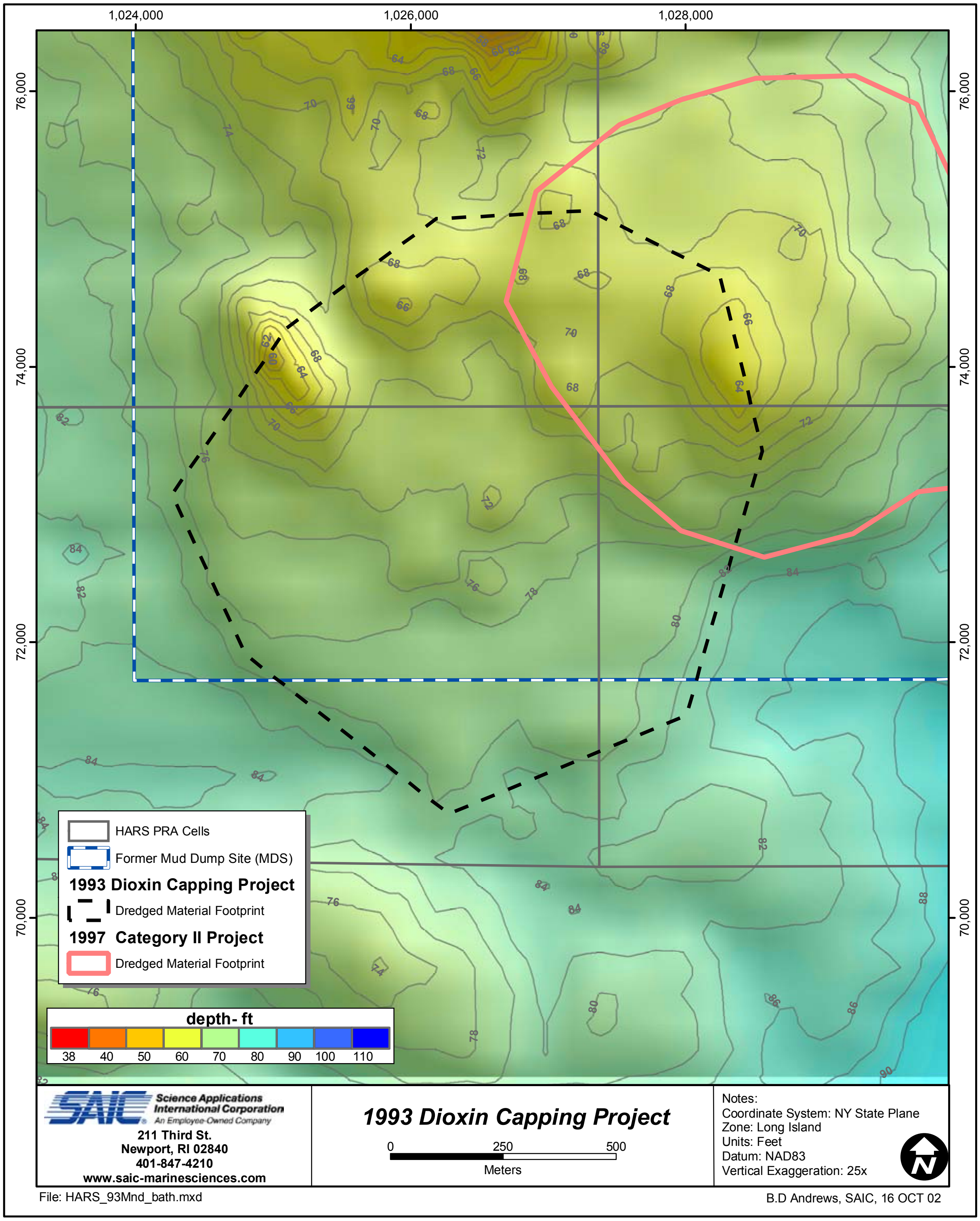


Figure 4.1-1. Bathymetric survey results for the 2002 survey over the 1993 Dioxin Mound

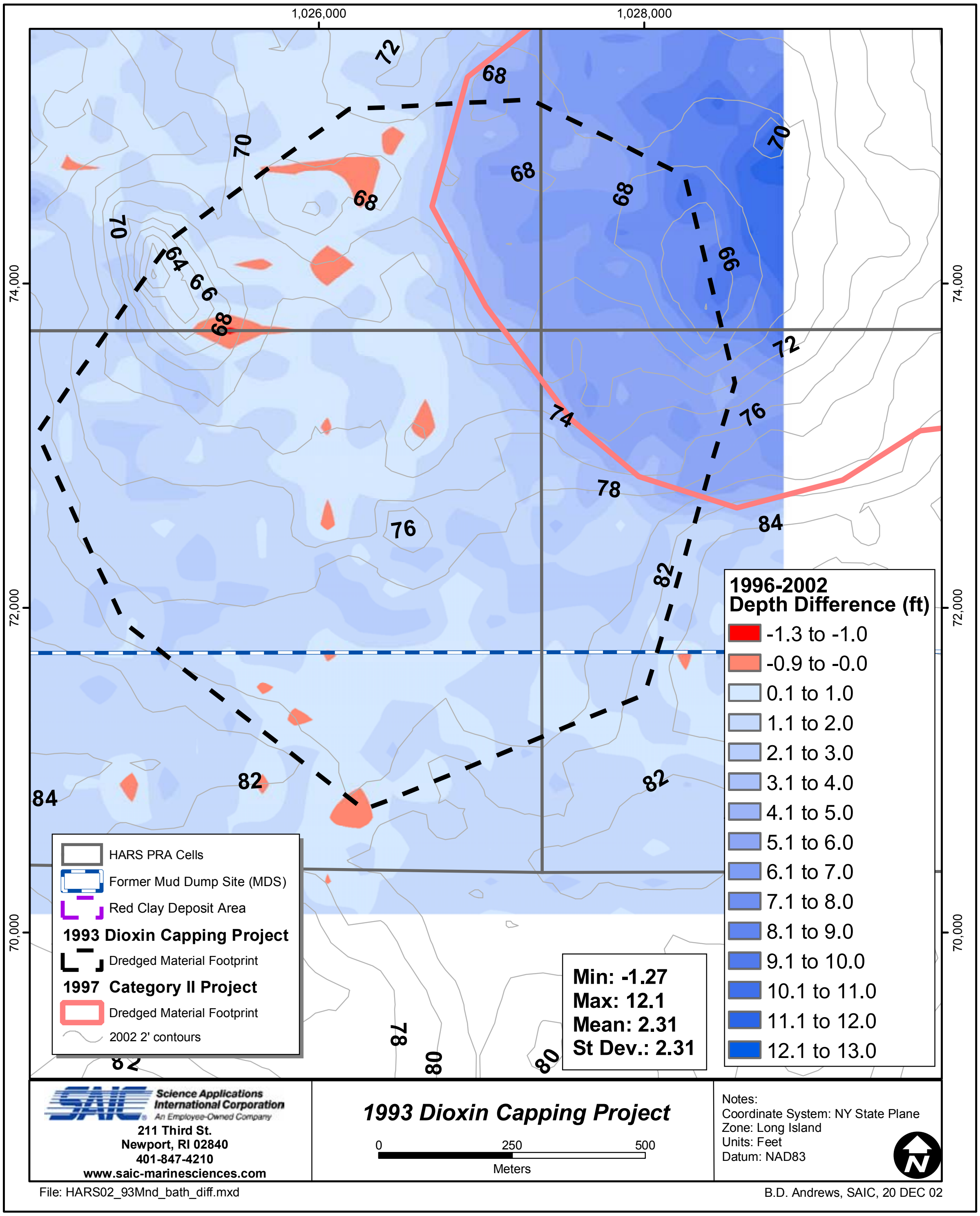


Figure 4.1-2. Bathymetric depth difference (in feet) between October 1996 and August 2002 surveys of the 1993 Dioxin Capping Project Mound

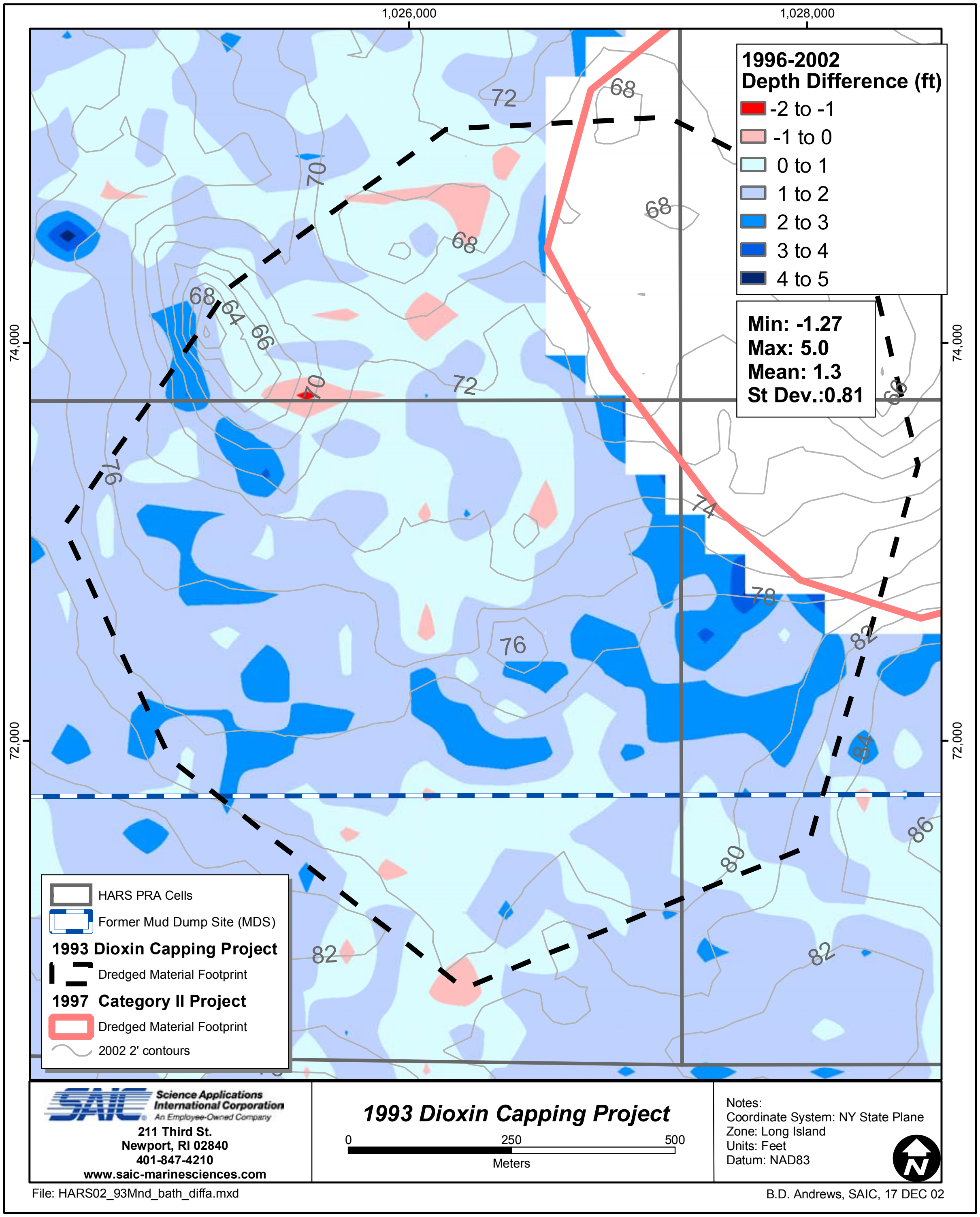


Figure 4.1-3. Bathymetric depth difference (in feet) between October 1996 and August 2002 surveys of the 1993 Dioxin Capping Project Area with the 1997 Category II Mound footprint excluded

random differences that would be expected when comparing two survey datasets that generally agreed well (Figure 4.1-4). As expected, this figure showed that all of the larger difference values (both positive and negative) were clustered within the areas of highest seafloor relief.

4.2 Sub-bottom Profiling Survey

4.2.1 2002 Survey Results

Because of the data formatting problems addressed in section 2.4.2, most of the sub-bottom profiling analysis was focused on the data acquired during the 15 north-south survey lanes that were run on 6 September 2002. Because these lanes were spaced at 500-foot intervals some resolution was lost in the resulting gridded data products. In addition, though the sand cap/dredged material interface could be reliably detected throughout most of the records, there were several areas where that interface could not be clearly distinguished, resulting in sporadic along-track data gaps in the digitized sub-bottom reflector files. These data gaps were primarily associated with areas where the sand cap reflector did not provide a distinct horizon or where the seafloor surface acoustic return masked the sand cap layer (Figure 4.2-1). Because of the strength of the acoustic return signal associated with the seafloor surface and the limited resolution of the sub-bottom system, the cap layer could not be clearly distinguished when it was less than 2 ft below the seafloor surface. Though the resulting gridded cap thickness models smoothed over any data gap areas, there was less confidence in the grid results over these areas (Figure 4.2-2).

Based on the gridded cap thickness model created from digitized north-south sub-bottom data, most of the area within the mound footprint appeared to be covered by around 5 to 7 feet of cap material, though the apparent acoustically detected cap thickness ranged from undetectable to over 10 ft (Figure 4.2-3). The greatest cap thickness occurred in the northeast portion of the mound, with a consistent thickness of 7 to 9 ft. In this area, the 1997 Category II Mound overlaps with the 1993 Dioxin Mound and the layering of cap material from the two projects was clearly indicated by the two distinct sub-bottom reflectors that were detected in the survey lanes passing over the area of overlap (Figure 4.2-4). Two other larger areas with apparent cap thickness greater than 8 ft were also indicated in the southern and western portions of the mound footprint.

The layer beneath the cap material reflector was presumed to be the historic dredged material deposit. Another distinct reflector periodically observed below the dredged material layer was identified as the probable dredged material/ambient sediment interface or basement sand reflector (Figure 4.2-5). This reflector was usually about 20–25 ft below the seafloor surface. Because the basement reflector was only detected intermittently along each lane, a gridded model of apparent dredged material thickness could not be generated. However, when the basement sand reflector was present, the cap/dredged material interface reflector was always detectable above it, indicating a sufficient sand cap over dredged material.

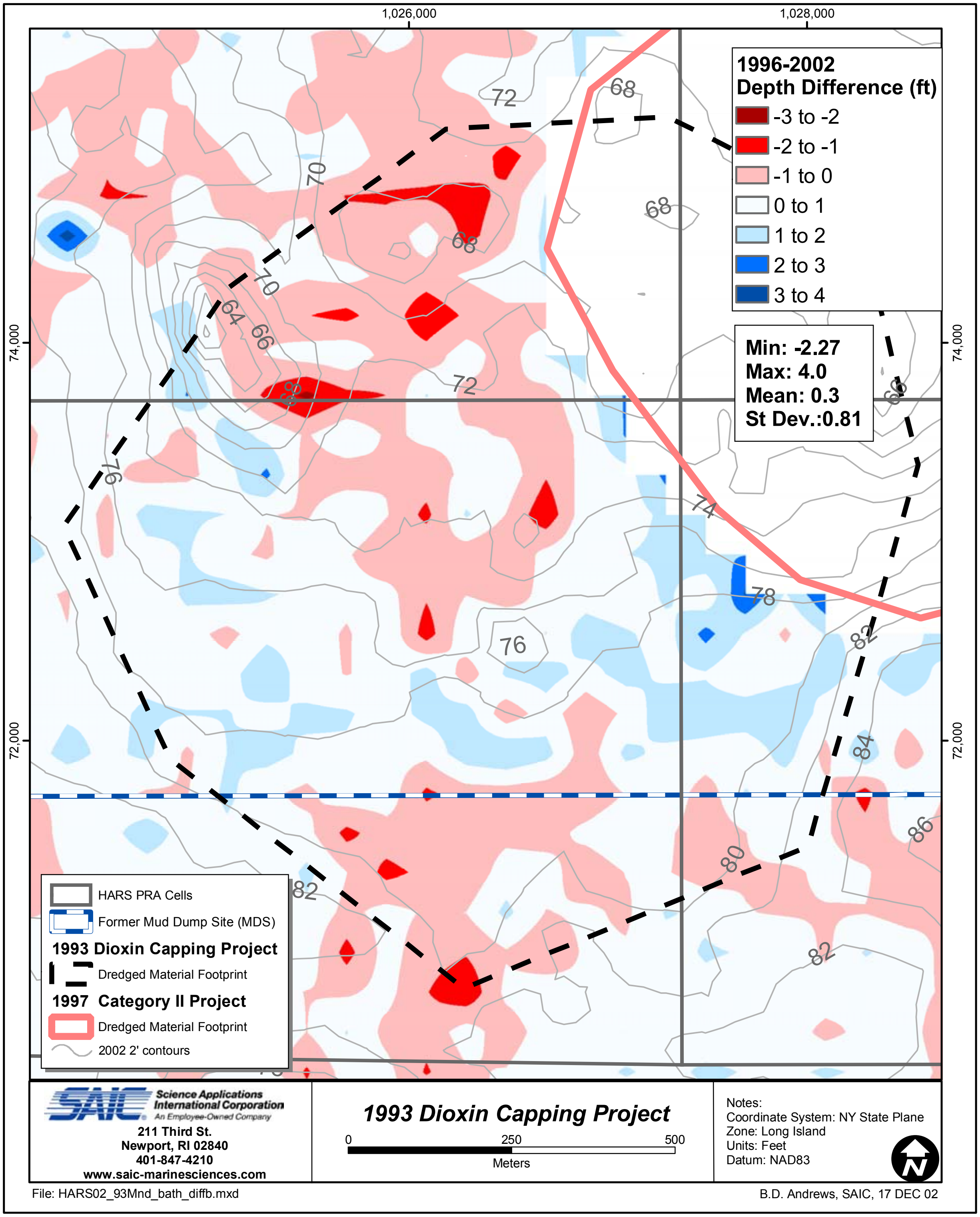


Figure 4.1-4. Bathymetric depth difference (in feet) between October 1996 (with -1 ft vertical correction) and August 2002 surveys of the 1993 Dioxin Mound Area

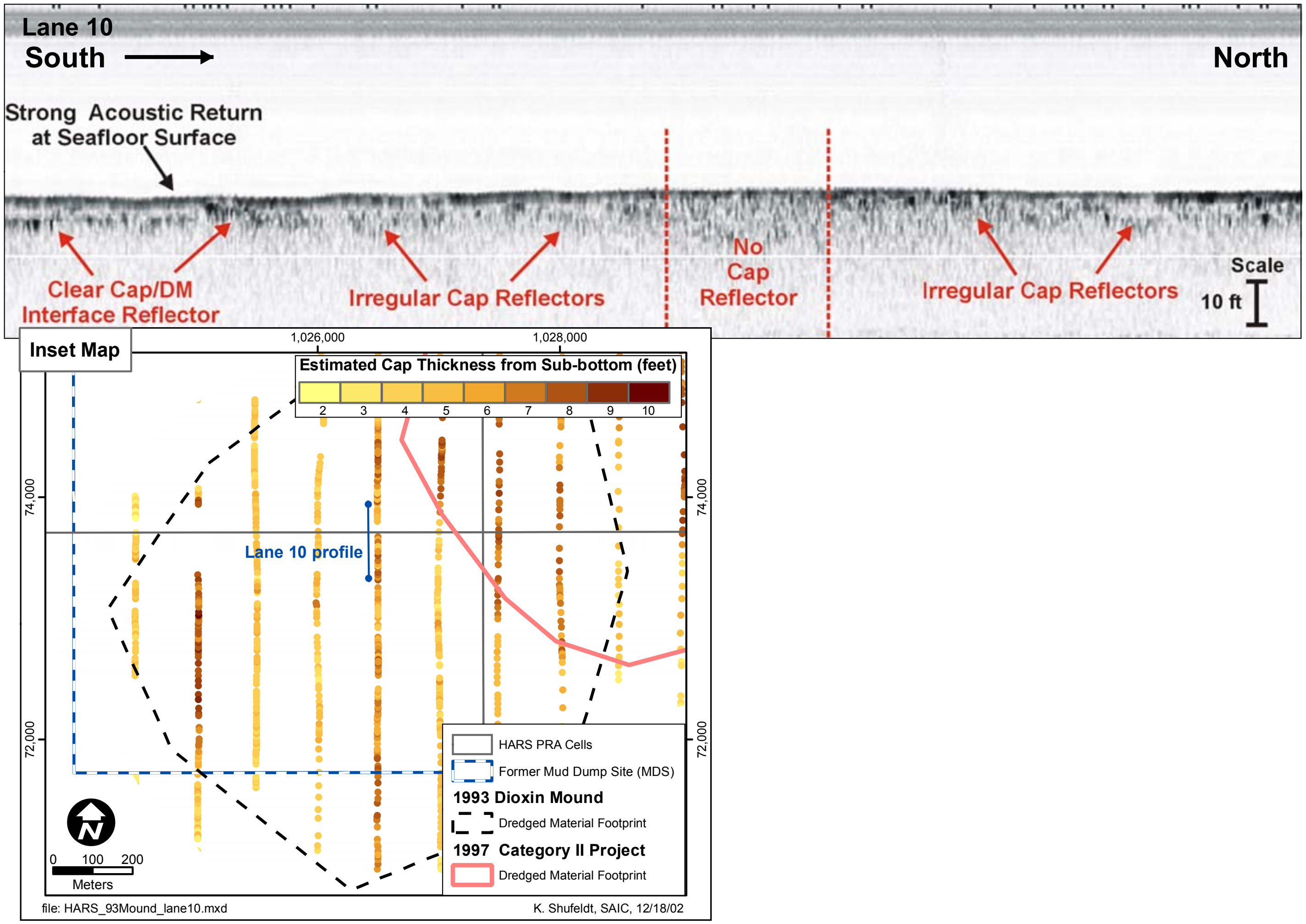


Figure 4.2-1. Representative sub-bottom profile record from a section of Lane 10 indicating the variability of the sand cap horizon below the surface reflector

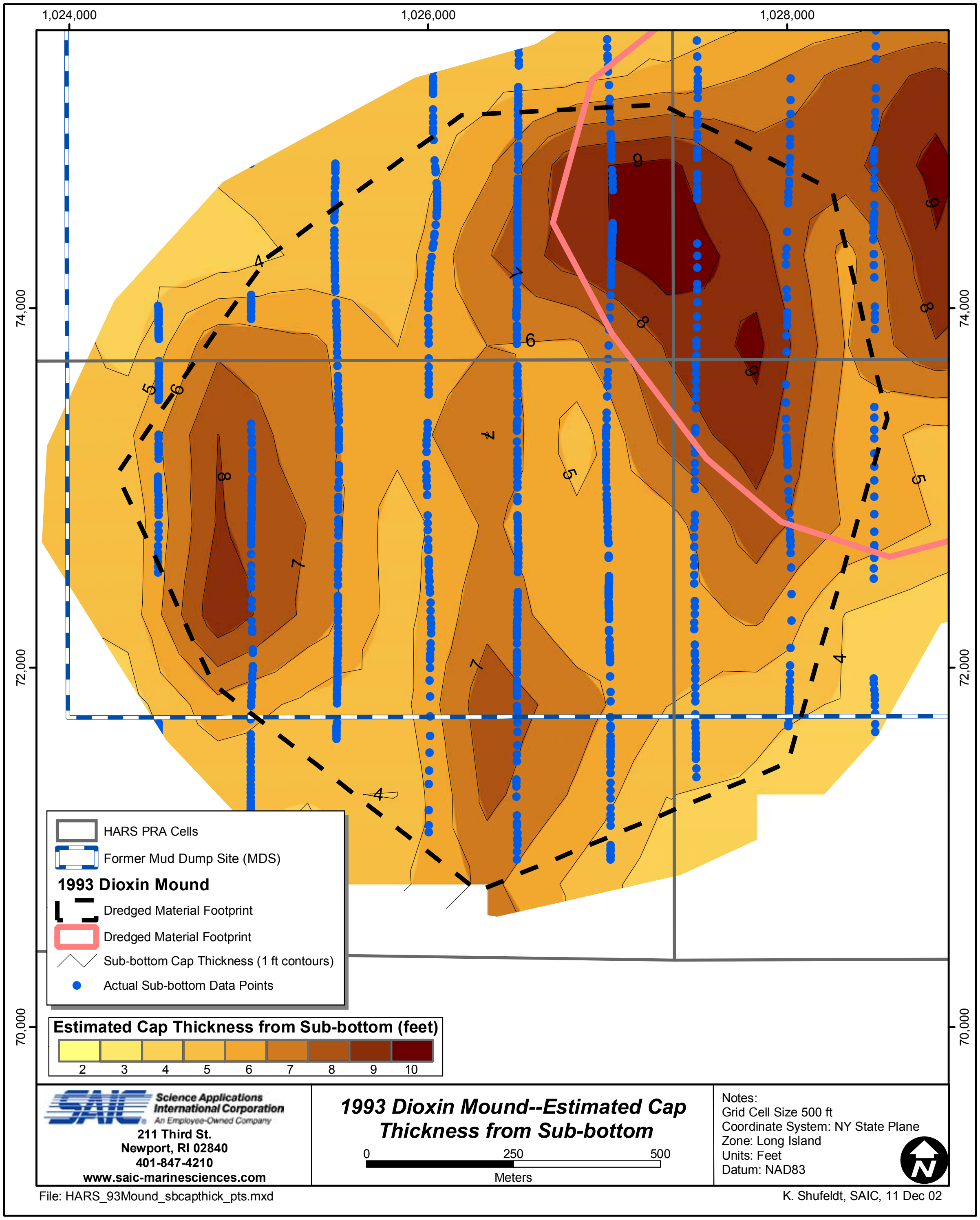


Figure 4.2-2. The 2002 survey track lines over the estimated sand cap thickness from the sub-bottom profile data over the 1993 Dioxin Mound

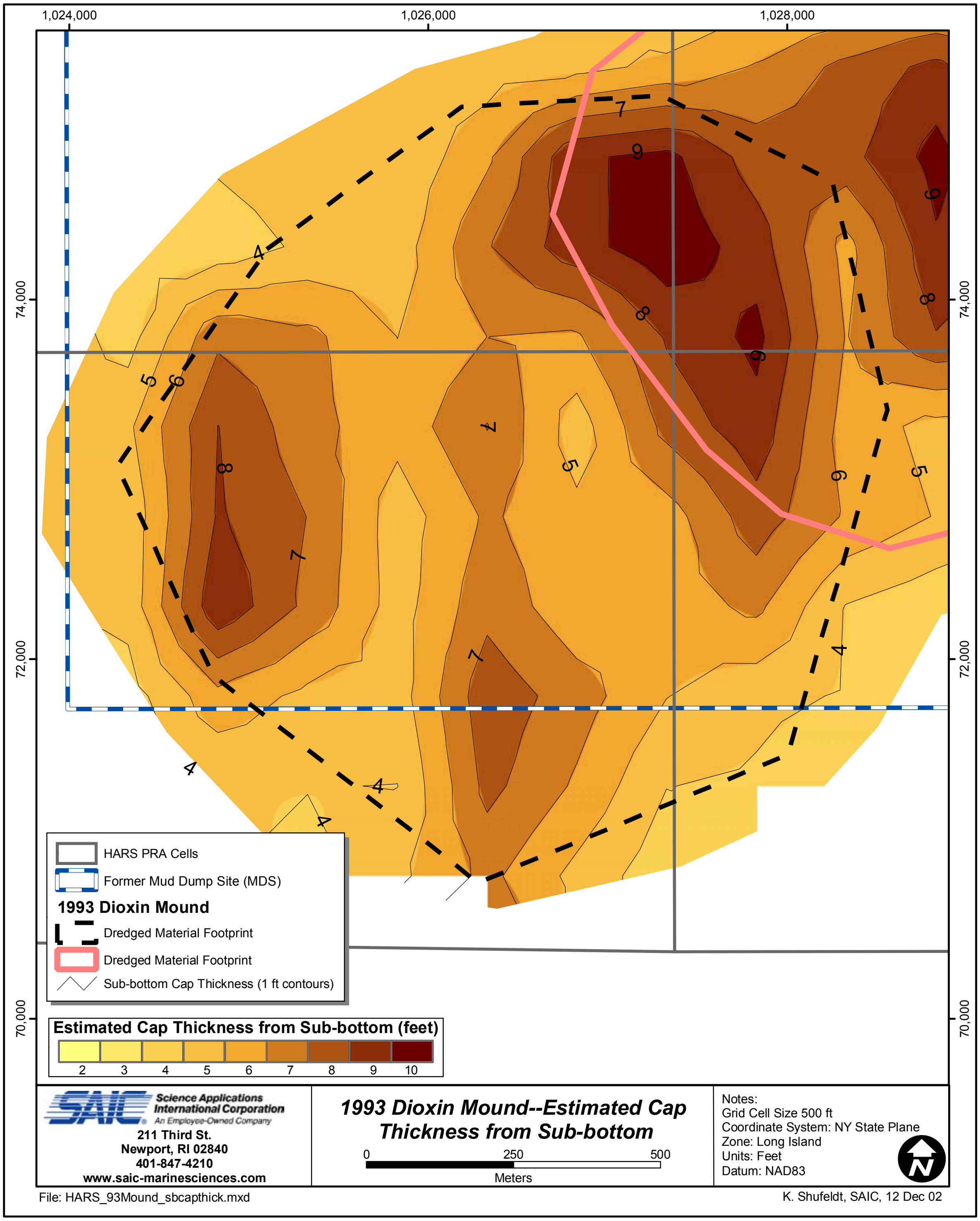


Figure 4.2-3. Estimated sand cap thickness from the 2002 sub-bottom profile data collected over the 1993 Dioxin Mound

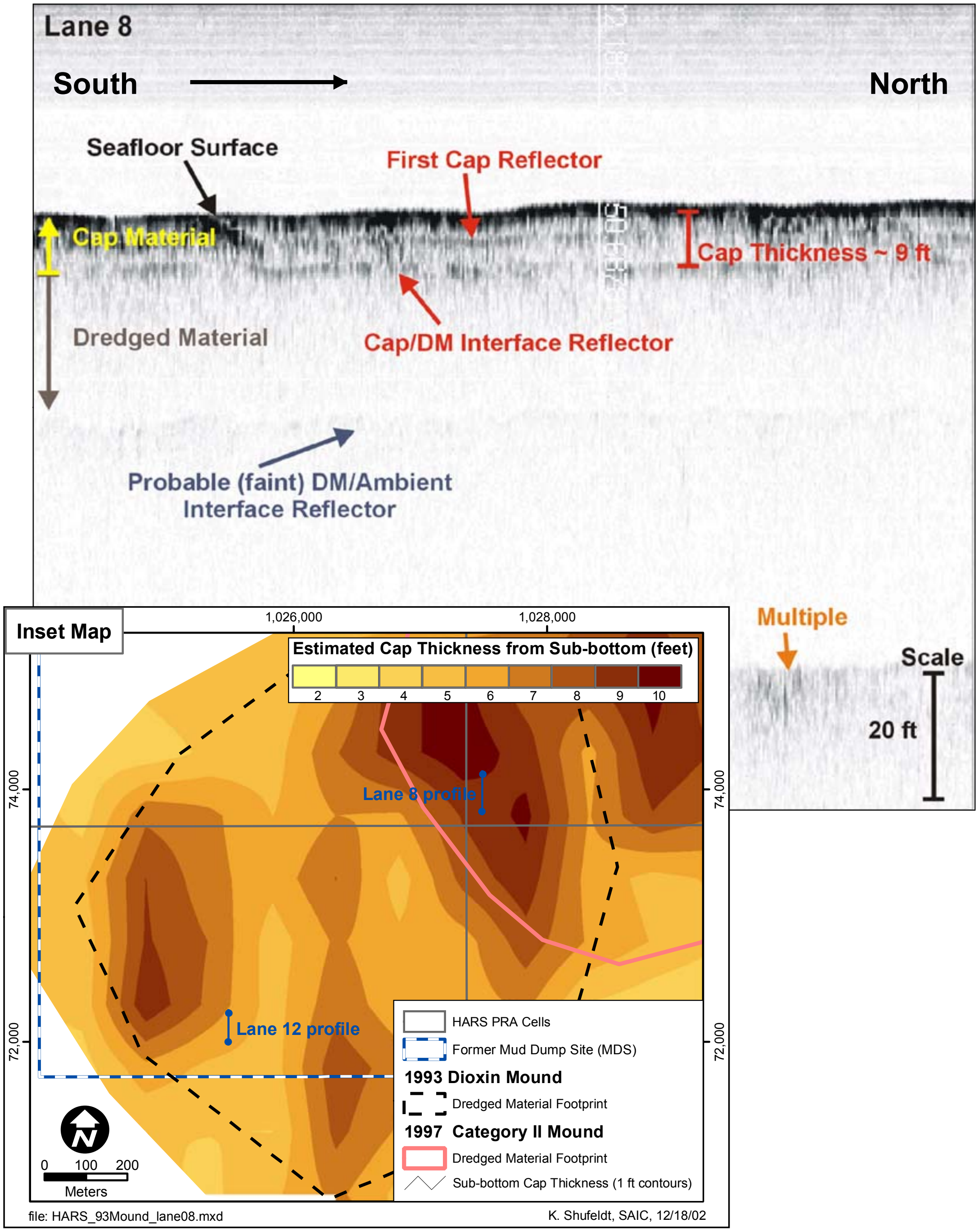


Figure 4.2-4. Representative sub-bottom profile record from a section of Lane 8 over the 1993 Dioxin Mound, where the 1993 and 1997 Mound Areas overlap (see inset). The sub-bottom record illustrates layering of the 1993 and 1997 sand cap material. The sand cap/dredged material interface is clearly defined approximately 10 feet below the seafloor surface.

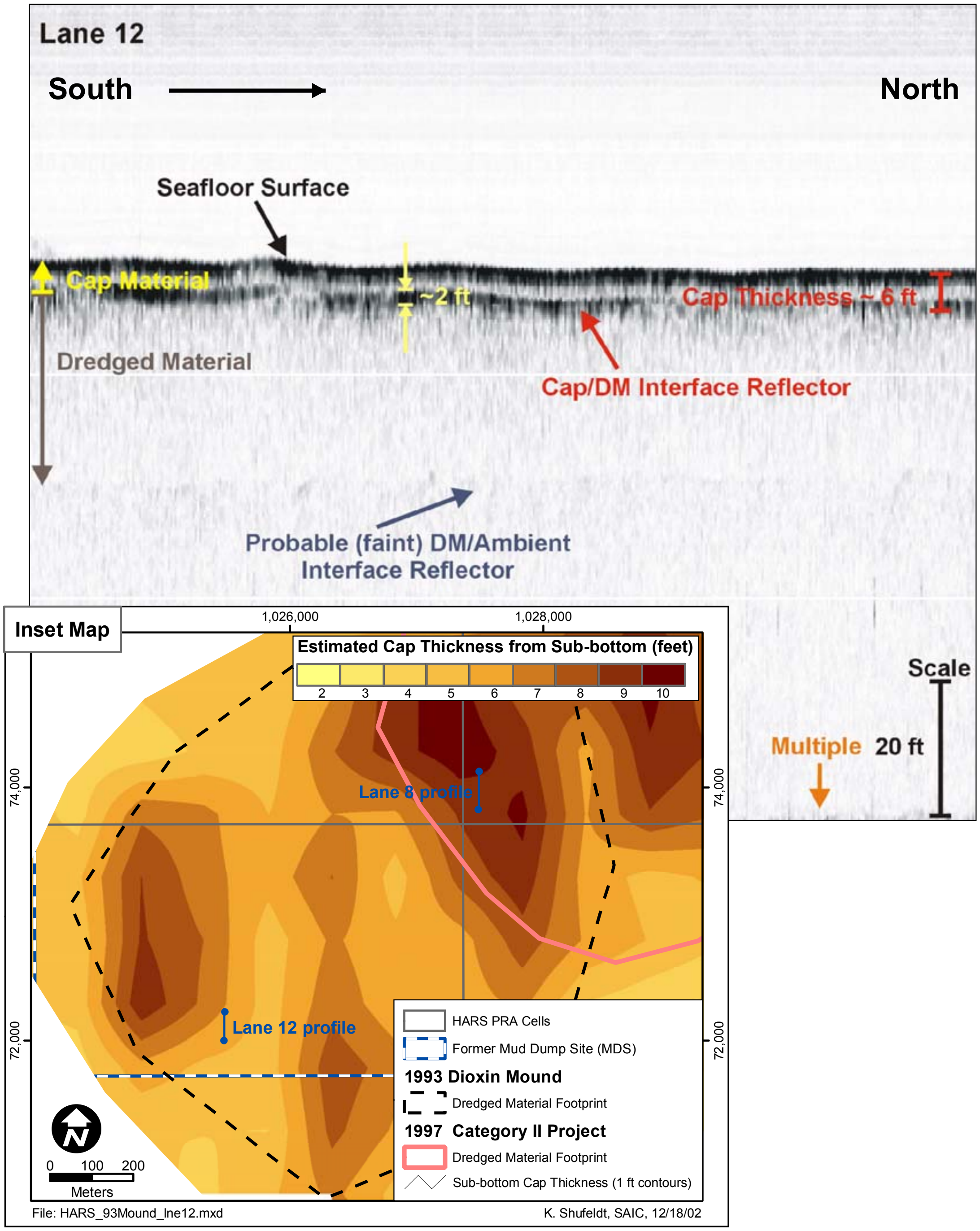


Figure 4.2-5. Representative sub-bottom profile record from a section of Lane 12 over the 1993 Dioxin Mound, illustrating the clear sand cap and dredged material interface. A sand cap thickness of approximately 7 feet is present. The inset map shows the location of the sub-bottom record over the mound.

4.2.2 Historic Survey Comparison

The most recent sub-bottom surveys over the 1993 Dioxin Mound prior to the 2002 survey were conducted in December 1993 and January 1994 (SAIC 1994, 1998), well before the 1997 Category II Capping Project. Because the northeast quadrant of the 1993 Dioxin Mound was heavily impacted by the 1997 capping project, this area was excluded from the comparisons with the prior survey. The 1993/94 sub-bottom survey reported a cap thickness range between 2 to >7 ft with most of the mound area apparently covered by an average of 4 to 6 ft of cap material (based on an assumed speed of sound of 1711 m/sec). As stated above, the 2002 survey results (outside of the northeast quadrant) indicated an average cap thickness of 5 to 7 ft, with two areas along the western and southern edges indicating a cap thickness of up to 9 ft. Though the measured cap thickness values were somewhat lower in the 1993/94 survey, this survey also indicated two similar thicker cap areas along the western and southern edges of the mound footprint.

Though the 2002 sub-bottom results indicated generally higher cap thickness values than the 1993/94 survey, the magnitude of this difference was generally only a foot or so. Given the large volume of sand (2.4 million cu yds) deposited during the 1997 capping project, it was likely that at least some portion of that material settled outside of the 1997 mound footprint, thereby creating increases in cap thickness over the 1993 Dioxin Mound (in areas outside of the northeast quadrant). Though it would be difficult to precisely quantify the possible increase in cap thickness as a result of the 1997 capping project, the bathymetric depth difference results indicated an average deposition of over one foot in the 1993 Dioxin Mound areas outside of the northeast quadrant (Figure 4.1-3).

Another potential factor contributing to the observed differences between the two sub-bottom surveys was the variability associated with the process of tracking and digitizing sub-bottom reflectors. Digitizing sub-bottom reflectors is a manual (and interpretive) process, and the results can be affected by the convention used when actually digitizing the points on the return. Because the measured thickness of the digital acoustic return signal may approach two feet (Figure 4.2-5), a good deal of variability can be introduced depending on what portion of the return signal was digitized.

4.3 Side-Scan Sonar Survey

A complete 100 kHz image mosaic, representing 100% side-scan sonar bottom coverage, was created for the entire 1993 Dioxin Mound (Figure 4.3-1). In the mosaic, darker areas represented stronger acoustic returns (higher reflectance) and indicated harder seafloor surface materials such as boulders or coarse sediment. The lighter areas of the mosaic represented weaker acoustic returns (lower reflectance) and indicated slightly softer seafloor surface material (silt or fine sand). Although some resolution was lost when creating the small-scale mosaic over a large area, the survey provided a useful overview of the site and enabled a broad seafloor characterization of the entire survey area.

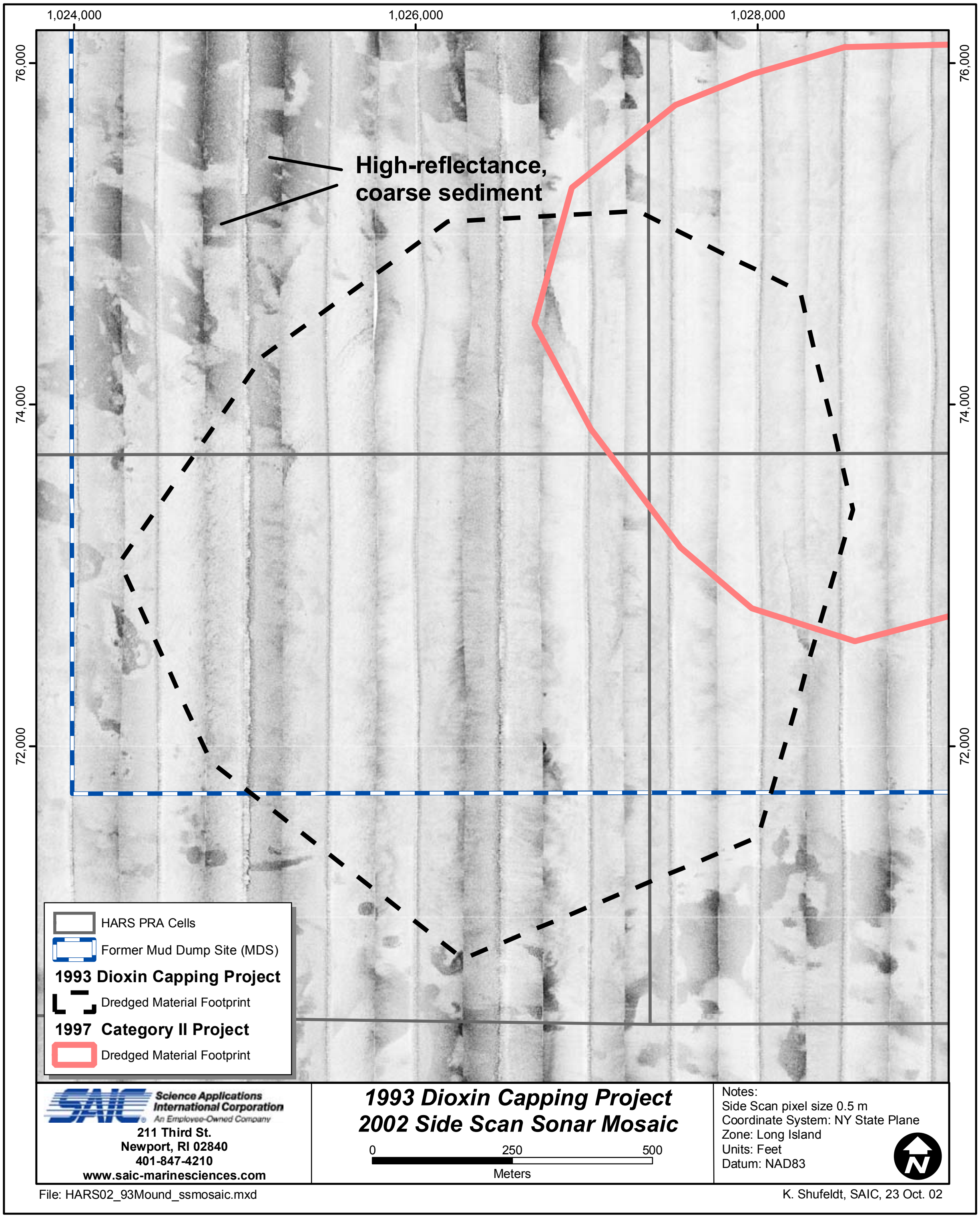


Figure 4.3-1. Side-scan sonar mosaic (100 kHz) over the 1993 Dioxin Mound

The full area mosaic shows the majority of the mound area (mostly inside the dredged material footprint) was characterized by lower reflectance acoustic returns that were indicative of finer bottom sediments, probably comprised of sand (Figure 4.3-1). However, higher-reflectance sediment was prominent in the side-scan sonar mosaic outside the dredged material footprint. Based on its darker acoustic return, it was most likely much coarser (coarse sand, gravel, and boulders) than the sediment over the disposal mound.

Along the edges of the higher-reflectance, coarser sediment deposits it appeared that these deposits were partially covered by the lower-reflectance mound sediment. As shown by the bathymetry/side-scan sonar data overlay, the distinct, higher-elevation bathymetry of the disposal mound encompassed approximately the same area as the lower-reflectance areas of the side-scan mosaic (Figure 4.3-2). An exception to this was the bathymetric high point along the northwest edge of the mound footprint that appeared to be associated with a large coarser grain sediment deposit. In the side-scan sonar mosaic no other distinct sediment types could be identified besides the finer sand (cap material) over the mound and the coarser sediment (ambient or historic dredged material) outside the mound. Dioxin-contaminated dredged material has been identified as finer grained sediment (mainly silt and clay) and should have a weaker acoustic return than any of the materials identified in the mosaic. These results suggested that the sand cap was still present over the 1993 Dioxin Mound.

4.4 REMOTS Sediment-Profile and Plan View Image Survey

REMOTS sediment-profile images and plan view results from the June 2002 survey of the 1993 Dioxin Capping Project Mound Area and the South Reference Area are presented below. The complete set of REMOTS image analysis results for the surveyed areas is provided in Appendix A; these results are summarized in Tables 4.4-1, 4.4-2, 4.4-3, and 4.4-4.

4.4.1 Cap Material Distribution and Physical Sediment Characteristics

In most of the REMOTS images acquired at the Area A stations on the sand cap, the depth of the sand cap layer exceeded the camera prism penetration depth (denoted by a greater than symbol in Table 4.4-1 and Figure 4.4-1). Therefore, cap material thickness measurements as determined by REMOTS represent conservative estimates.

Dredged material is recognized in REMOTS images by the presence of low reflectance silt-clay sediments with chaotic fabrics or layered stratigraphy. A small patch of apparent relic dredged material was observed under a layer of sand cap material in one of the replicate images from Station A18 (Figures 4.4-1 and 4.4-2). One of the two replicate images at Station A22 displayed a relic dredged material layer that was deeper than the camera prism penetration depth; no sand cap was visible. In the other replicate image at Station A22, the dredged material was identified as a laterally discontinuous layer underlying a thin surface layer of clean sand (Figure 4.4-3). The sand-over-dredged-material stratigraphy at some Area “A” stations may indicate localized areas where discrete puddles of dredged material have been covered by a thin layer of sand.

Well-sorted, fine-grained sand presumed to be cap material was found at several of the Area B stations (B4, B5, B7, B8, B9, B11 and B12) located on the outer edges of the sand cap (Table 4.4-2 and Figure 4.4-1). At the remaining Area B stations and at most of the Area C stations,

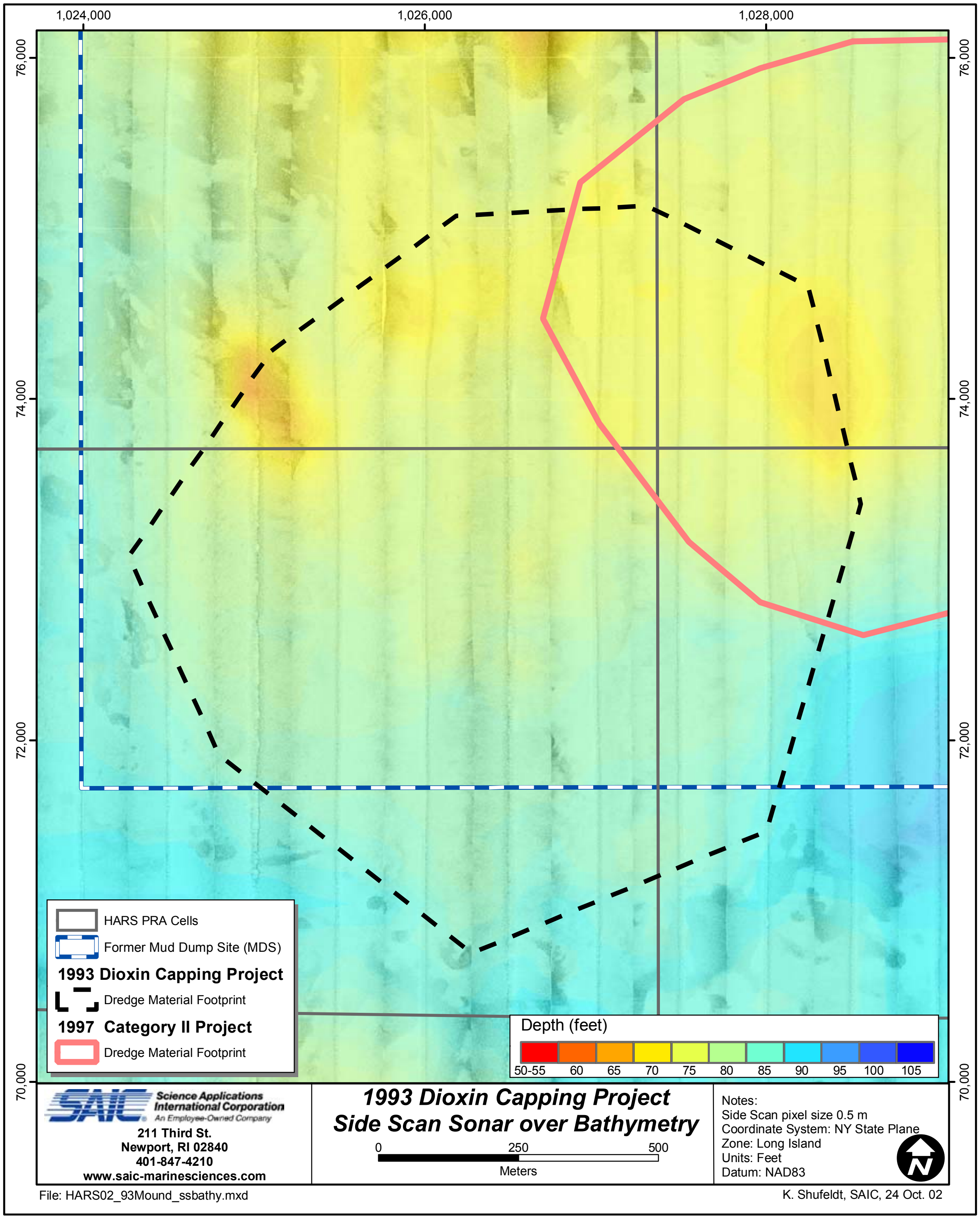


Figure 4.3-2. Composite map illustrating the 2002 bathymetric data overlaid on the side-scan sonar mosaic to demonstrate the correlation between seafloor composition and topography at the 1993 Dioxin Mound

Table 4.4-1.
Summary of 2002 REMOTS Results for Area A Stations

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Cap Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	aRPD Mean (cm)	OSI Mean
A1	2 to 1 phi (2)	6.2	0.0	0	> 6.2	2.2	SA.M (2)	ST I (2)	> 6.2	7.0
A10	3 to 2 phi (2)	8.1	0.0	0	> 8.1	0.6	SA.F (2)	ST I (2)	3.9	5.5
A11	3 to 2 phi (2)	4.4	0.0	0	> 4.5	2.9	SA.F (2)	ST I (2)	> 4.5	7.0
A12	2 to 1 phi (1), 3 to 2 phi (1)	4.9	0.0	0	> 4.9	2.4	SA.F (1), SA.M (1)	ST I (1), ST I to II (1)	2.4	5.5
A13	3 to 2 phi (2)	6.1	0.0	0	> 6.1	1.9	SA.F (2)	ST I (2)	3.4	5.5
A14	3 to 2 phi (2)	4.0	0.0	0	> 4.0	1.7	SA.F (2)	ST I (2)	> 4.0	6.5
A15	3 to 2 phi (2)	6.3	0.0	0	> 6.3	3.3	SA.F (2)	ST I (2)	> 6.3	7.0
A16	3 to 2 phi (2)	3.1	0.0	0	> 3.1	1.0	SA.F (2)	ST I (1), ST I to II (1)	1.3	3.5
A17	3 to 2 phi (2)	3.7	0.0	0	> 3.7	2.8	SA.F (2)	ST I to II (2)	3.3	6.5
A18	> 4 phi (2)	9.5	0.0	0	5.6	2.1	SA.F (2)	ST I (1), ST II (1)	2.3	5.5
A19	2 to 1 phi (1), 3 to 2 phi (1)	5.0	0.0	0	> 5.0	1.2	SA.F (1), SA.M (1)	ST I (2)	4.4	6.5
A2	3 to 2 phi (2)	2.8	0.0	0	> 2.8	2.1	SA.F (2)	ST I (2)	> 2.8	5.0
A20	2 to 1 phi (1), 3 to 2 phi (1)	4.1	0.0	0	> 4.1	2.2	SA.M (2)	ST I (2)	3.6	6.0
A21	3 to 2 phi (2)	3.7	0.0	0	> 3.7	2.7	SA.F (2)	ST I (2)	2.4	4.5
A22	> 4 phi (1), 3 to 2 phi (1)	8.4	> 3.6	1	4.5	1.0	UN.SI (1), UN.SS (1)	ST II (1), ST II on III (1)	2.0	7.0
A23	3 to 2 phi (2)	5.2	0.0	0	> 5.2	2.9	SA.F (1), SA.M (1)	ST I (2)	> 5.2	7.0
A24	3 to 2 phi (2)	4.6	0.0	0	> 4.6	2.5	SA.F (2)	ST I (2)	> 4.6	7.0
A25	3 to 2 phi (2)	4.7	0.0	0	> 4.7	2.5	SA.F (2)	ST I (1), ST I to II (1)	> 4.7	7.5
A3	2 to 1 phi (1), 3 to 2 phi (1)	4.6	0.0	0	> 4.6	1.3	SA.F (1), SA.M (1)	ST I (2)	> 4.6	6.5
A4	2 to 1 phi (1), 3 to 2 phi (1)	6.5	0.0	0	> 6.5	1.1	SA.F (1), SA.M (1)	ST I (2)	> 6.5	7.0
A5	3 to 2 phi (2)	2.7	0.0	0	> 2.7	2.5	SA.F (2)	ST I (2)	> 2.7	5.0
A6	3 to 2 phi (2)	4.4	0.0	0	> 4.4	0.8	SA.F (2)	ST I (2)	> 4.4	6.5
A7	3 to 2 phi (2)	5.3	0.0	0	> 5.3	1.2	SA.F (2)	ST I (2)	4.0	5.5
A8	3 to 2 phi (2)	4.0	0.0	0	> 4.0	3.0	SA.F (2)	ST I (2)	2.6	5.0
A9	3 to 2 phi (2)	4.3	0.0	0	> 4.3	3.4	SA.F (1), SA.M (1)	ST I (2)	> 4.3	7.0
AVG		5.1	0.1	0.0	> 4.8	2.0			3.9	6.1
MAX		9.5	> 3.6	1.0	> 8.1	3.4			> 6.5	7.5
MIN		2.7	0.0	0.0	> 2.7	0.6			1.3	3.5

Table 4.4-2.
Summary of 2002 REMOTS Results for Area B Stations

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Cap Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	aRPD Mean (cm)	OSI Mean
B1	2 to 1 phi (1), 4 to 3 phi (1)	6.7	0.0	0	0.0	1.5	HR (1), SA.M (1)	ST I (2)	3.3	6.0
B10	< -1 phi (1), 4 to 3 phi (1)	2.0	0.0	0	0.0	0.8	HR (1), UN.SS (1)	INDET (2)	INDET	INDET
B11	> 4 phi (1), 3 to 2 phi (1)	11.7	> 11.7	2	4.4	1.5	SA.F (1), UN.SI (1)	ST I (1), ST I on III (1)	2.4	6.5
B12	3 to 2 phi (2)	4.7	0.0	0	> 4.7	1.6	SA.F (2)	ST I (2)	3.2	5.5
B13	4 to 3 phi (2)	6.5	> 6.5	2	0.0	0.7	UN.SS (2)	ST I to II (2)	2.5	5.5
B2	> 4 phi (2)	10.1	> 10.1	2	0.0	0.6	UN.SI (2)	ST I (2)	3.1	5.5
B3	> 4 phi (2)	10.4	0.0	0	0.0	0.8	UN.SI (2)	ST I (2)	3.2	5.5
B4	3 to 2 phi (2)	4.2	0.0	0	> 4.2	1.9	SA.F (2)	ST I (2)	> 4.2	6.5
B5	3 to 2 phi (2)	3.8	0.0	0	> 3.8	1.2	SA.F (2)	ST I (2)	> 3.8	6.0
B6	> 4 phi (1), 3 to 2 phi (1)	5.7	4.2	1	0.0	2.7	SA.F (1), UN.SS (1)	ST I (2)	2.2	4.0
B7	3 to 2 phi (2)	4.2	0.0	0	> 4.2	2.6	SA.F (2)	ST I (2)	> 4.2	6.0
B8	> 4 phi (1), 3 to 2 phi (1)	13.4	7.0	1	2.7	0.7	SA.F (1), UN.SI (1)	ST I on III (1), ST I to II (1)	3.0	8.0
B9	3 to 2 phi (2)	4.3	0.0	0	> 4.3	0.8	SA.F (2)	ST I (1), ST I to II (1)	3.9	6.5
AVG		6.8	3.0	0.6	2.2	1.3			3.3	6.0
MAX		13.4	> 11.7	2.0	4.7	2.7			> 4.2	8.0
MIN		2.0	0.0	0.0	0.0	0.6			2.2	4.0

Table 4.4-3.
Summary of 2002 REMOTS Results for Area C Stations

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Cap Material Thickness Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	aRPD Mean (cm)	OSI Mean
C1	3 to 2 phi (2)	4.7	0.0	0	2.2	1.6	SA.F (1), SA.M (1)	ST I (1), ST I on III (1)	2.3	9.0
C10	3 to 2 phi (1), 4 to 3 phi (1)	3.1	0.0	0	0.0	0.8	SA.F (1), UN.SS (1)	ST I (2)	> 3.1	5.5
C11	1 to 0 phi (2)	3.6	0.0	0	0.0	0.9	SA.G (2)	ST I (2)	2.1	4.5
C12	3 to 2 phi (2)	4.0	0.0	0	> 4.0	1.6	SA.F (2)	ST I (1), ST I to II (1)	> 4.0	6.5
C2	3 to 2 phi (2)	3.8	0.0	0	> 3.9	1.4	SA.F (2)	ST I (2)	> 3.9	7.0
C3	2 to 1 phi (1), 3 to 2 phi (1)	5.7	0.0	0	> 5.7	4.5	SA.F (1), SA.M (1)	ST I (2)	> 5.7	7.0
C4	2 to 1 phi (2)	5.0	0.0	0	> 5.0	1.6	SA.M (2)	ST I (2)	3.5	6.0
C5	2 to 1 phi (2)	4.3	0.0	0	> 4.3	2.0	SA.M (2)	ST I (2)	> 4.3	7.0
C6	> 4 phi (2)	14.3	> 14.3	2	0.0	0.5	UN.SI (1), UN.SS (1)	ST II on III (2)	2.8	9.0
C7	> 4 phi (2)	9.0	> 9.0	2	0.0	0.4	UN.SI (2)	ST I on III (1), ST II to III (1)	2.1	8.0
C8	> 4 phi (2)	12.2	> 12.2	2	0.0	0.4	UN.SI (2)	ST I (1), ST I on III (1)	1.6	5.5
C9	< -1 phi (1), 4 to 3 phi (1)	5.5	0.0	0	0.0	1.7	SA.G (1), UN.SS (1)	ST I to II (1), ST II on III (1)	> 5.5	11.0
AVG		6.3	3.0	0.5	2.1	1.5			3.4	7.2
MAX		14.3	>14.3	2.0	> 5.7	4.5			> 5.7	11.0
MIN		3.1	0.0	0.0	0.0	0.4			1.6	4.5

Table 4.4-4.
Summary of 2002 REMOTS Results for the South Reference Area (SREF)

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	aRPD Mean (cm)	OSI Mean
SREF10	3 to 2 phi (2)	4.3	0.7	SA.F (2)	ST I (2)	> 4.3	7.0
SREF11	3 to 2 phi (2)	6.2	1.1	SA.F (2)	ST I (2)	3.7	6.0
SREF14	3 to 2 phi (2)	4.4	0.8	SA.F (2)	ST I (2)	> 4.4	7.0
SREF16	3 to 2 phi (2)	4.7	1.0	SA.F (2)	ST I (2)	2.9	5.5
SREF18	3 to 2 phi (2)	4.9	0.5	SA.F (2)	ST I (2)	> 4.9	7.0
SREF20	3 to 2 phi (1), 4 to 3 phi (1)	6.2	0.4	SA.F (2)	ST I (2)	4.3	6.0
SREF3	2 to 1 phi (2)	6.2	1.7	SA.M (2)	ST I (2)	> 6.2	7.0
SREF4	3 to 2 phi (2)	5.1	0.3	SA.F (2)	ST I (2)	> 5.1	6.5
SREF5	3 to 2 phi (2)	6.3	1.1	SA.F (2)	ST I (2)	> 6.3	7.0
SREF8	3 to 2 phi (2)	5.4	0.5	SA.F (2)	ST I (2)	3.2	5.5
AVG		5.4	0.8			4.5	6.5
MAX		6.3	1.7			> 6.3	7.0
MIN		4.3	0.3			2.9	5.5

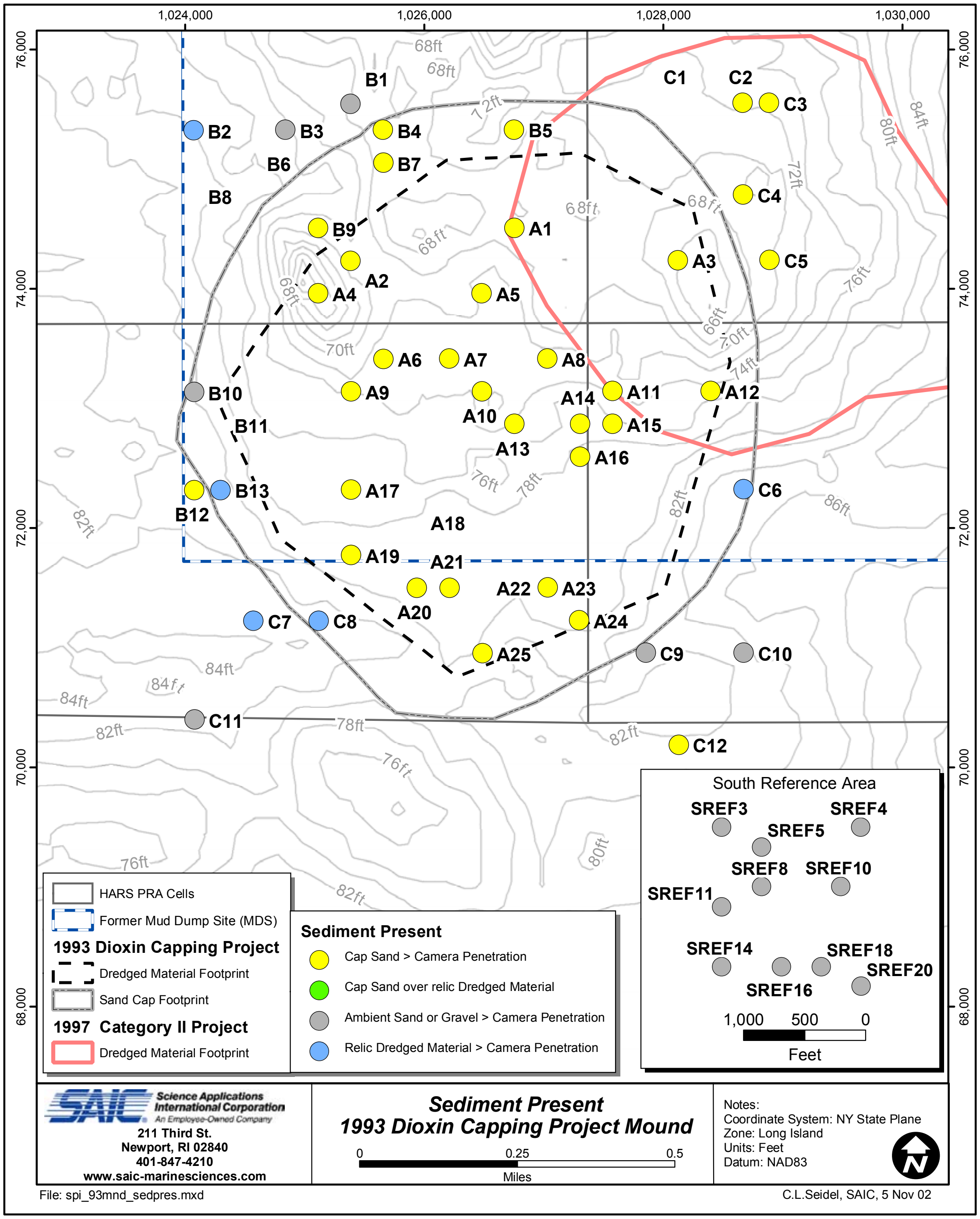


Figure 4.4-1. Map showing the distribution of cap material and dredged material at the 2002 REMOTS stations over the 1993 Dioxin Capping Project Area. Bathymetric contours are from the summer 2002 bathymetry survey. Multi-colored symbols at a station indicate two different results for the two replicate images. See Figure 1.2-1 for the location of the South Reference Area in relation to the HARS.

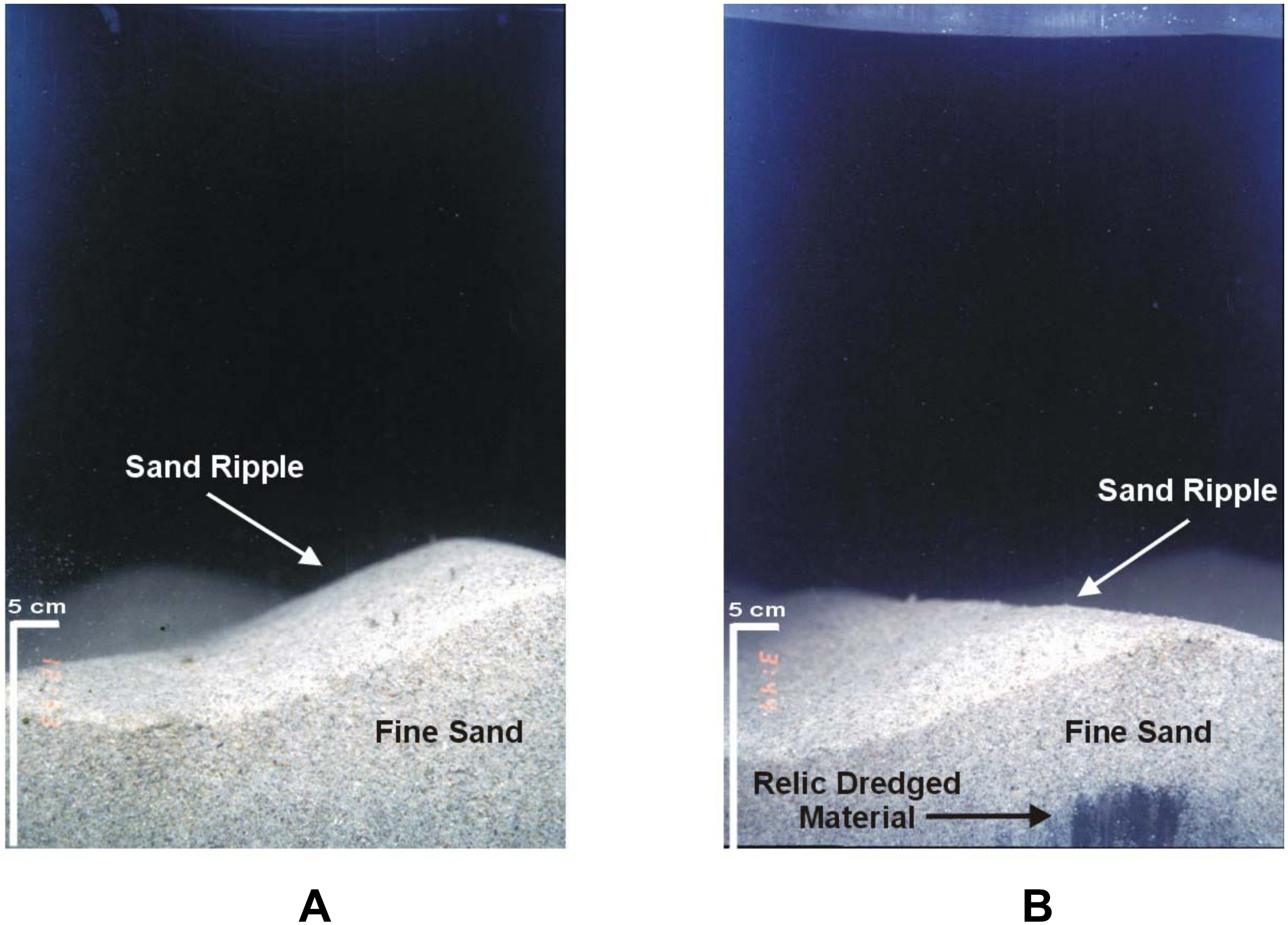


Figure 4.4-2. REMOTS images from Stations A11 (A) and A21 (B) illustrating well-sorted, rippled fine sand (benthic habitat SA.F and grain size major mode of 3 to 2 phi) comprising a homogenous sand cap layer over the 1993 Dioxin Mound. In image B, an isolated clast of apparent fine-grained relic dredged material occurs under the sand cap layer.

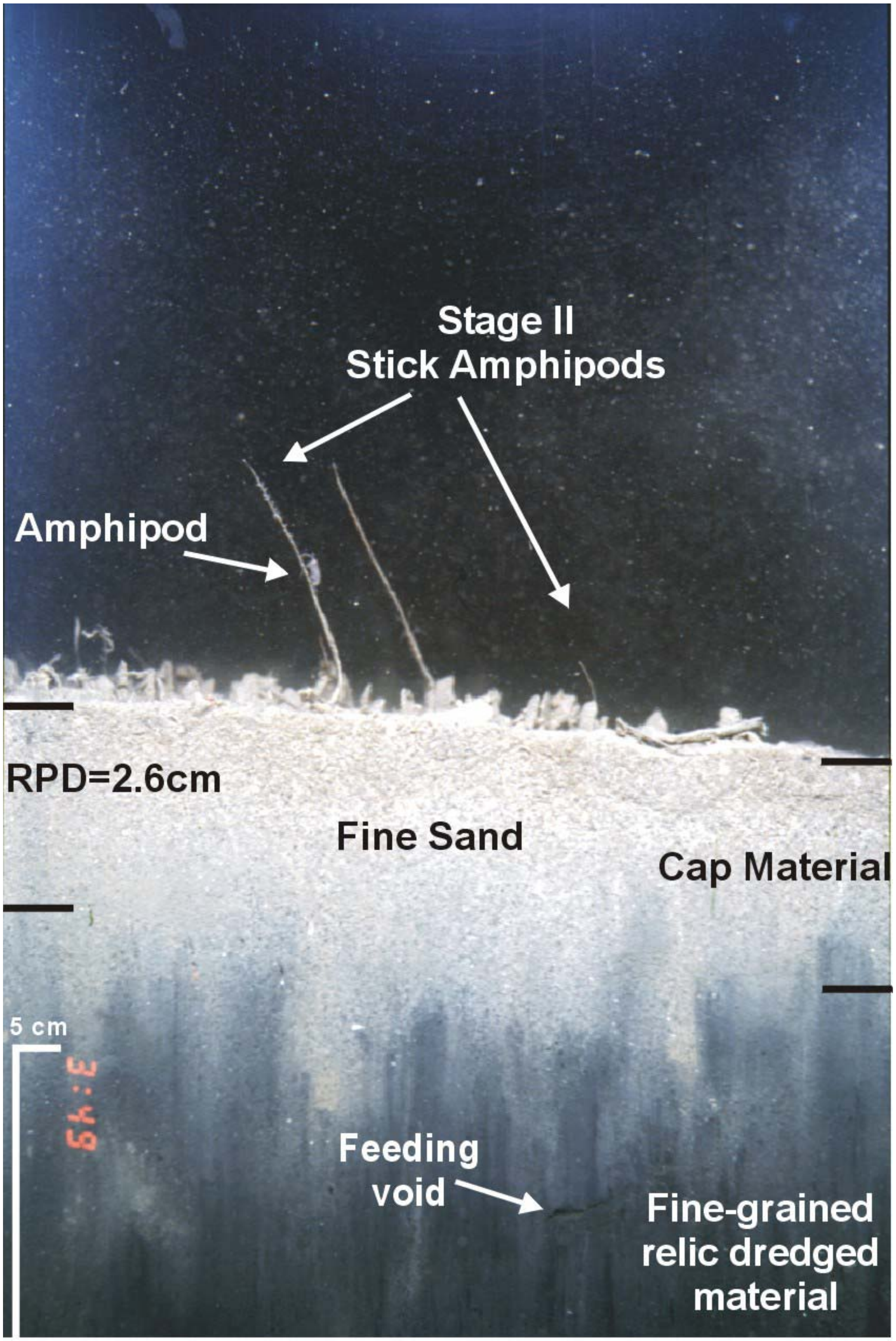


Figure 4.4-3. REMOTS image obtained from Station A22 displaying an apparent sand cap layer over fine-grained relic dredged material (benthic habitat type UN.SS)

greater variability in sediment type was related to the presence of either older, uncapped dredged material or firmer ambient sand/gravel bottom. Several stations outside of the project perimeter had dredged material present (Tables 4.4-2 and 4.4-3; Figure 4.4-1). At most of these stations, the dredged material consisted of low-reflectance, fine-grained sediment (silt-clay), which extended from the seabed surface to below the camera's imaging depth. The dredged material was covered by a layer of clean sand cap in replicate images at Stations B8 and B11 (e.g., Figure 4.4-4). It is likely that the dredged material at stations in Areas B and C is not associated with the 1993 Dioxin Capping Project, since it lies beyond the original disposal mound footprint, but rather represents relic material resulting from historic disposal activities in the southern part of the former Mud Dump Site.

4.4.1.1 Sediment Grain Size

The grain size major mode of the 50 A, B and C stations located in and around the 1993 Capping Project area was 3–2 phi, indicating predominately well-sorted fine sand (Tables 4.4-1, 4.4-2, and 4.4-3; Figures 4.4-2 and 4.4-5). Ten of the total surveyed stations had at least one replicate image showing a slightly coarser material component of medium sand that ranged from 2 to 1 phi, and replicates at three stations displayed a larger grain size major mode of 1 to 0 phi or < –1 phi (Figure 4.4-6). There was little variability in grain size major mode among A stations within the capped area; only two replicate images displayed softer, fine-grained silt-clay (> 4 phi at Stations A18 and A22).

There was more variability in sediment grain size among B and C stations in the areas adjacent to the sand cap. In these areas, surface sediments ranging in size from < -1 phi (gravel) to > 4 phi (silt-clay) were noted (Tables 4.4-2 and 4.4-3; Figure 4.4-6). The finer grained sediments (grain size major modes of >4 phi) were indicative of historic dredged material deposits that flank the fringes of the 1993 Dioxin Capping Project Mound Area. Relic dredged material (either uncapped or capped with sand) was present at 5 of the 13 B stations and at 3 of the 12 C stations. Both fine sand (4–3 phi) and medium sand (2 to 1 phi) were prevalent at C stations corresponding to the overlapping 1997 Category II Capping Project Area.

The South Reference Area was dominated by ambient fine sand (grain size major mode of 3 to 2 phi) in all but three replicate images (Table 4.4-4 and Figure 4.4-5). The sand tended to be well sorted and rippled. Medium sand (2 to 1 phi) was observed at Station SREF3 in the northwestern portion of the sampling area (Figure 4.4-6). Conversely, a higher fraction of finer-grained material (silty sands) occurred in one replicate of Station 20 located near the southeast corner of the South Reference Area; this finer-grained material is apparently correlated with increasing water depths and less current scouring in the southeast corner. No relic dredged material or cap sand layers were detected at the South Reference Area.

4.4.1.2 Benthic Habitat

The primary benthic habitat classification for the Area A stations was fine sand (habitat type SA.F) occurring in 38 of the 50 replicate images (76%; Table 4.4-1 and Figures 4.4-2 and 4.4-7). However, muddy sediment with a high apparent proportion of very fine sand (habitat type UN.SS) and unconsolidated silty sediment (habitat type UN.SI) was detected at Station A22 located in the southern portion of the cap footprint (Figure 4.4-3). Benthic habitat types at the

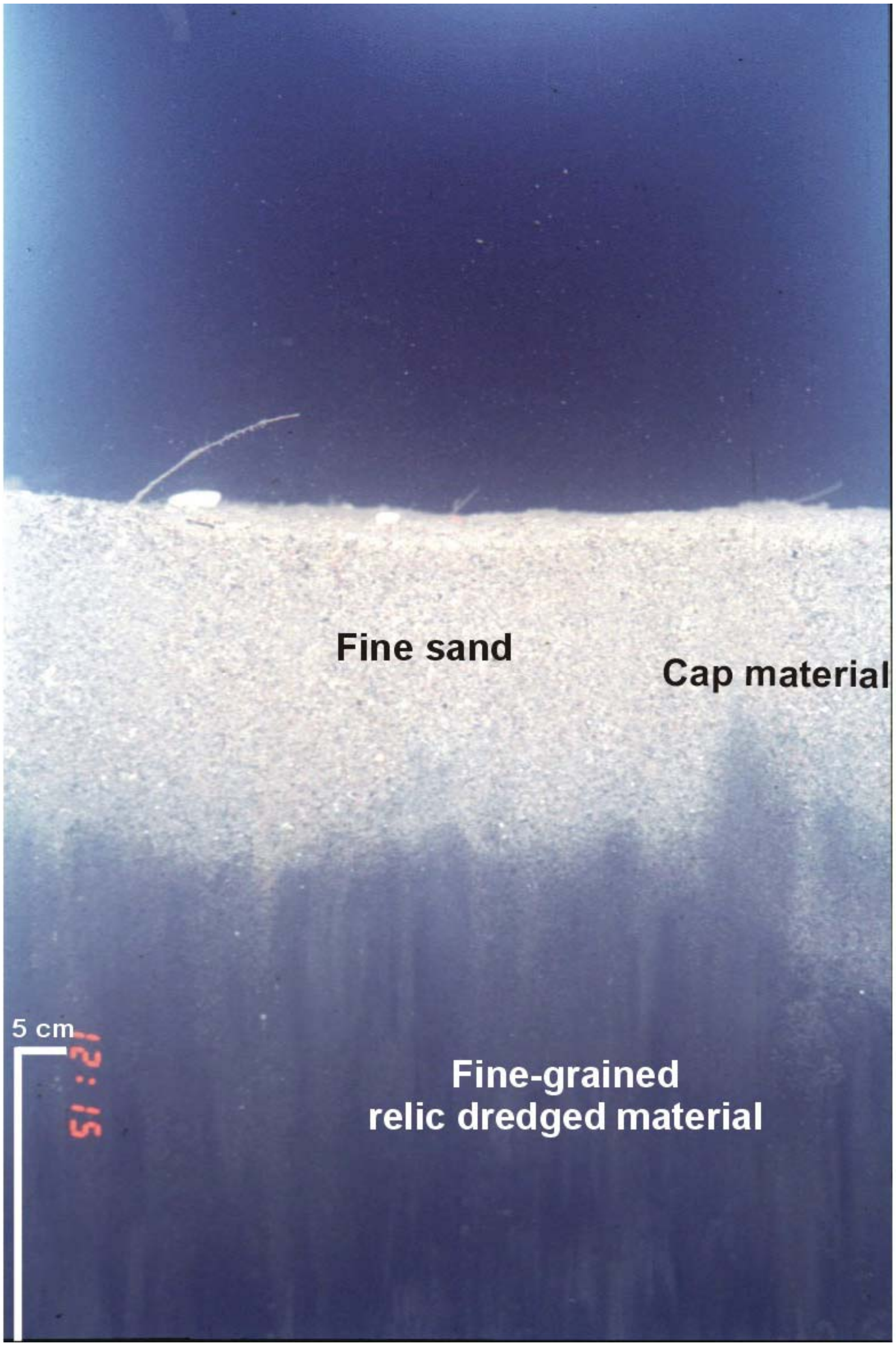


Figure 4.4-4. REMOTS image collected from Station B8, located outside the sand cap footprint, displaying a layer of high-reflectance sand cap over fine-grained relic dredged material

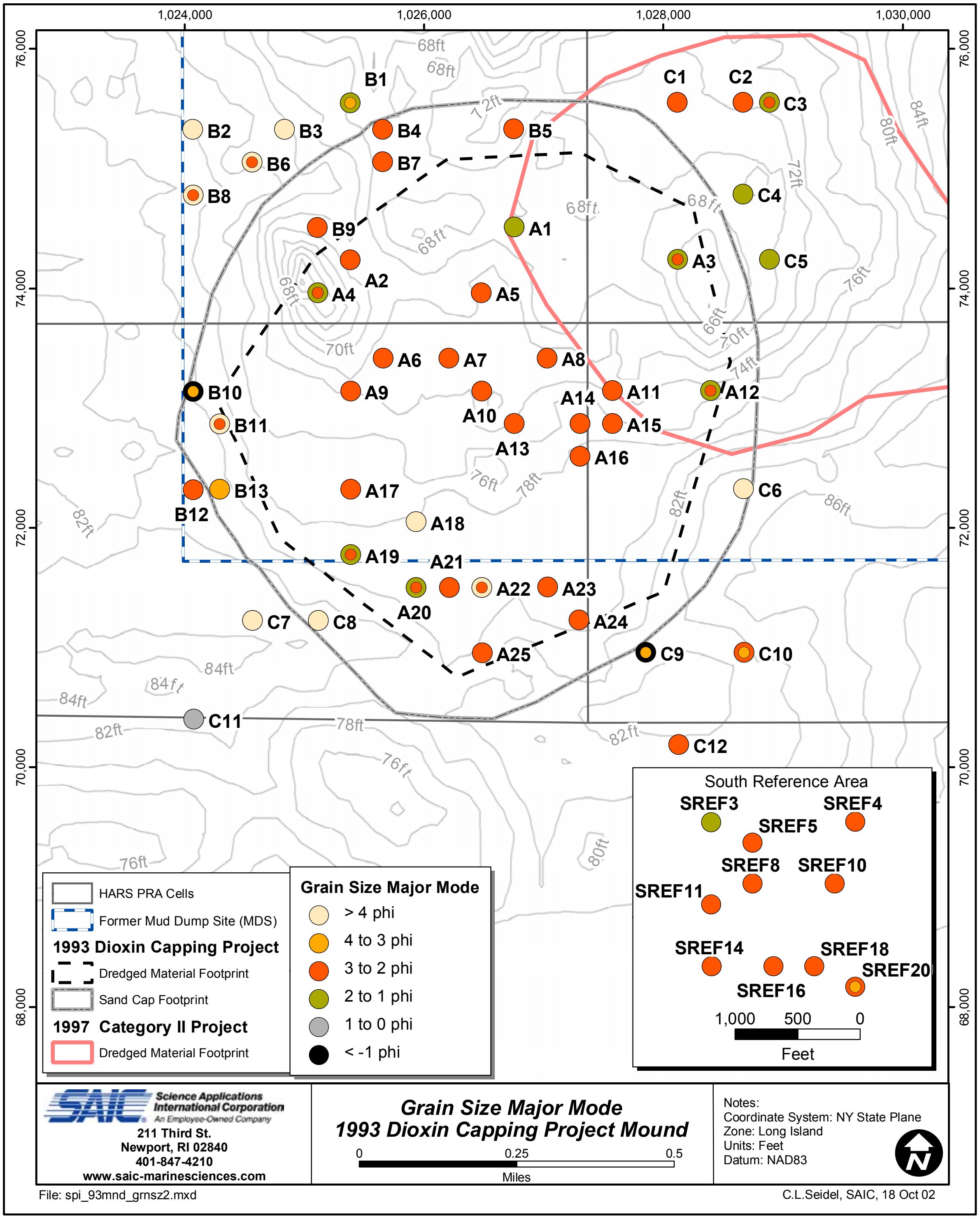


Figure 4.4-5. Map showing the grain size major mode (in phi units) at the 2002 REMOTS stations over the 1993 Dioxin Capping Project Area

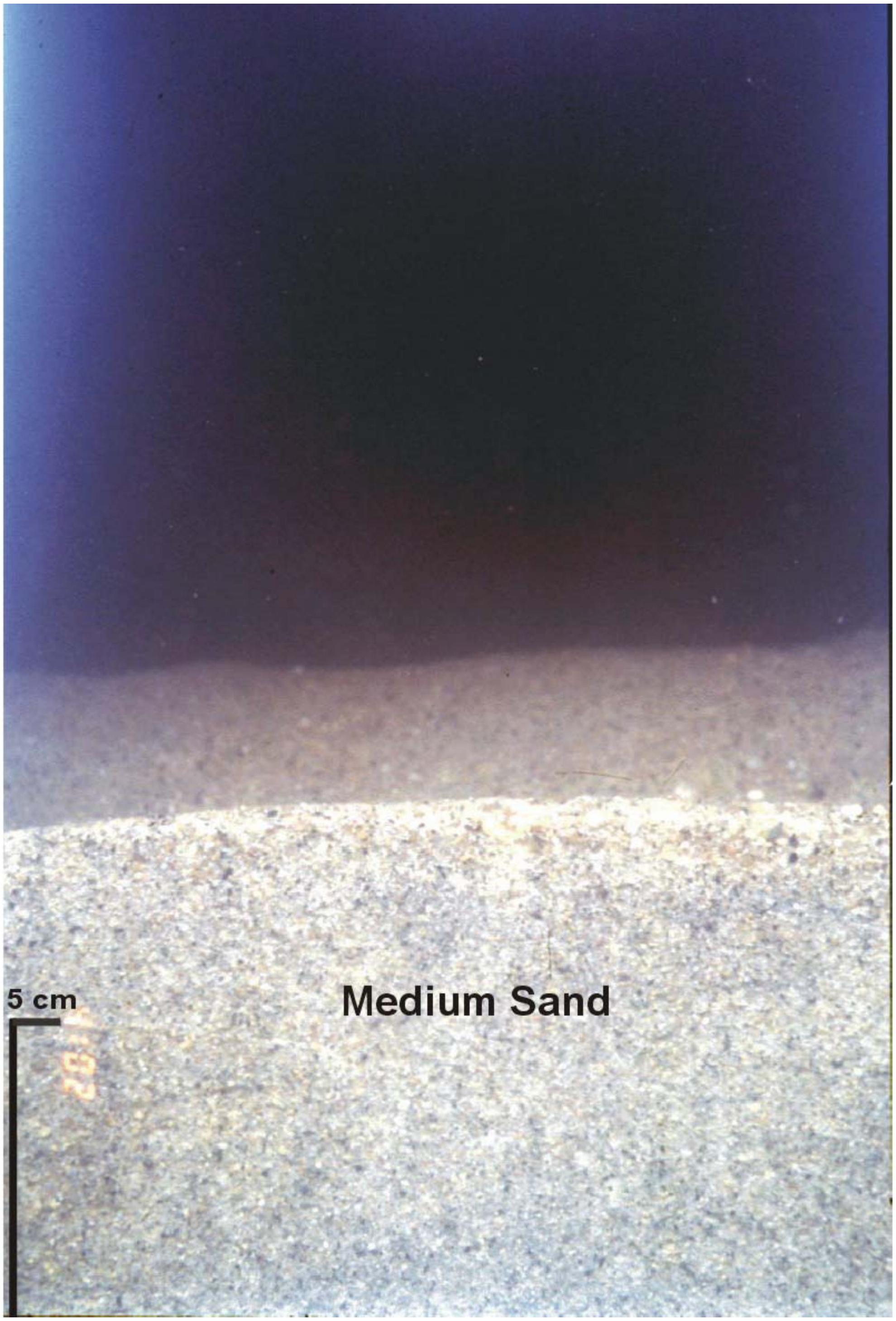


Figure 4.4-6. REMOTS image from South Reference Area Station SREF3 illustrating homogenous rippled medium sand (grain size major mode of 2 to 1 phi) and benthic habitat type SA.M. The aRPD depth extends beyond the camera prism penetration (> 8.1 cm).

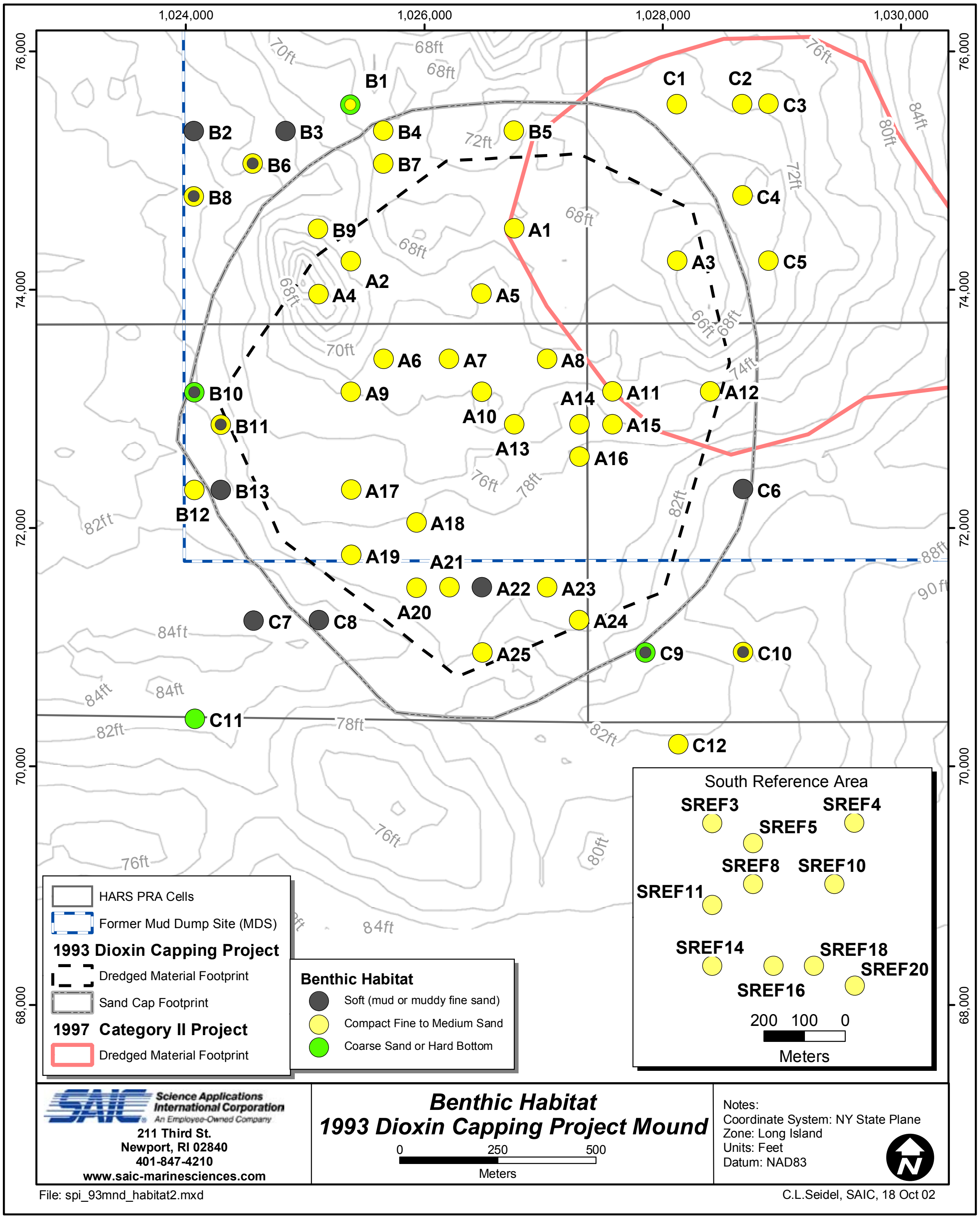


Figure 4.4-7. Benthic habitat classifications at the 2002 REMOTS stations over the 1993 Dioxin Capping Project Area

Area A were similar to those at the South Reference Area, with fine sand (benthic habitat type SA.F) occurring in all but one station (Table 4.4-4 and Figure 4.4-7). Consistent with grain size results at this station (SREF3), larger grained sediment resulted in the benthic habitat classification SA.M (medium sand) (Figure 4.4-6).

A variety of benthic habitat types (UN.SI, UN.SS, SA.F, SA.M, SA.G, and HR) were observed among B and C stations in areas adjacent to the sand cap, however the primary benthic habitat classification was fine sand (habitat type SA.F) at the B stations occurring in 50% of the replicate images (Table 4.4-2 and Figure 4.4-7). Hard bottom conditions consisting of encrusted cobble and rock (habitat type HR) were detected in one replicate image each at stations B1 and B10. A relatively even mixture of habitat types SA.F, SA.M, UN.SS, and UN.SI was observed at the Area C stations (Table 4.4-3 and Figure 4.4-7). One replicate image from Station C9 located in the southeastern corner of the surveyed area was classified as ambient sediment composed of medium sand with gravel (habitat type SA.G) due to the considerable presence of gravel (Figure 4.4-8).

4.4.1.3 Camera Penetration

The depth of penetration of the REMOTS camera prism can be used to map gradients in the bearing strength (hardness) of the sediment. This hardness parameter is useful for distinguishing between a relatively thick (>20 cm) layer of sand cap material or soft bottom related to the presence of thin caps or underlying silt/clay. Freshly deposited sediments or older, highly bioturbated sediments tend to be soft, while compacted sands are hard and resist camera prism penetration. Because the camera prism was loaded with the maximum number of lead weights throughout the survey, the vertical force of the prism against the bottom was a constant. Observed differences in penetration depth therefore reflect the state of sediment compaction and bearing strength.

Mean camera prism penetration measurements at the Area A stations ranged from 2.7 cm at Station A5 to 9.5 cm at Station A18, with an overall average of 5.1 cm (Table 4.4-1 and Figure 4.4-9). These low camera prism measurements reflect the compact sand cap that tended to resist deep penetration of the sediment-profile camera. The deeper penetration of 9.5 cm observed at Station A18 is attributed to the softer sediments (> 4 phi) observed at this station. Overall, the relatively narrow range of values of the remaining stations suggested spatial uniformity in geotechnical properties of the cap within the capping boundary.

Mean camera prism penetration measurements were slightly deeper at the surrounding B and C stations, with overall measurements of 6.8 cm and 6.3 cm, respectively (Tables 4.4-2 and 4.4-3; Figure 4.4-9). Penetration values > 7 cm were observed at a number of stations that were occupied beyond the capping boundary at several B and C stations (Figure 4.4-9). Penetration depths at the Area B stations ranged from approximately 2.0 cm at Station B10 to 13.4 cm at Station B8, indicating small-scale sediment variability within and amongst stations (Table 4.4-2). Similarly, mean camera prism measurements at Area C stations ranged from 3.1 cm at Station C10 to 14.3 cm at Station C6 (Table 4.4-3). The deeper penetration values represent uncapped or only thinly capped and/or bioturbated older dredged materials lying beyond the project boundary, while the lower penetration values indicate the possible presence of sand cap material

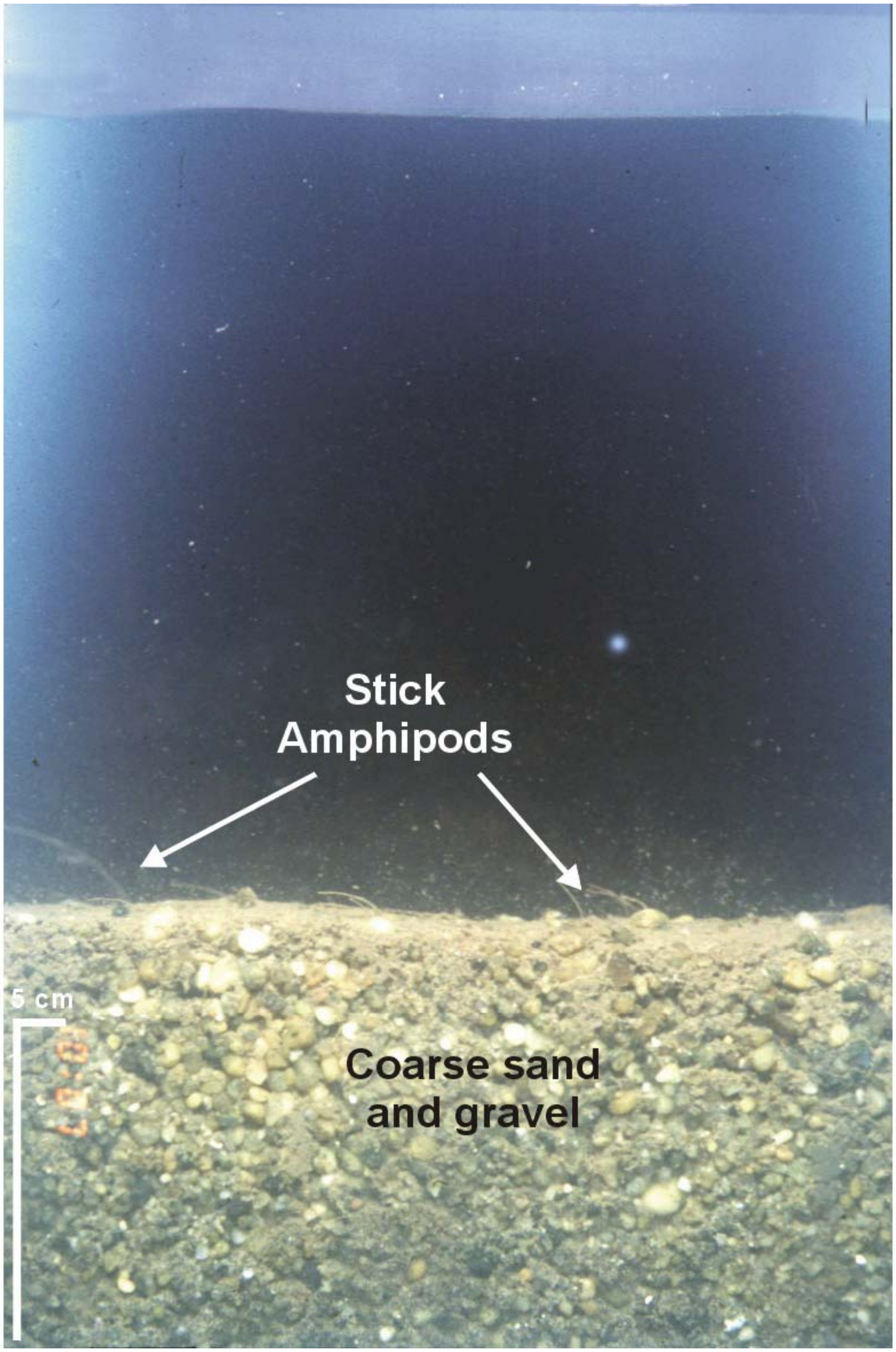


Figure 4.4-8. REMOTS image from Station C9, located outside the sand cap footprint, displaying ambient coarse sand and gravel (benthic habitat type SA.G). Stage II stick amphipods are visible at the sediment surface.

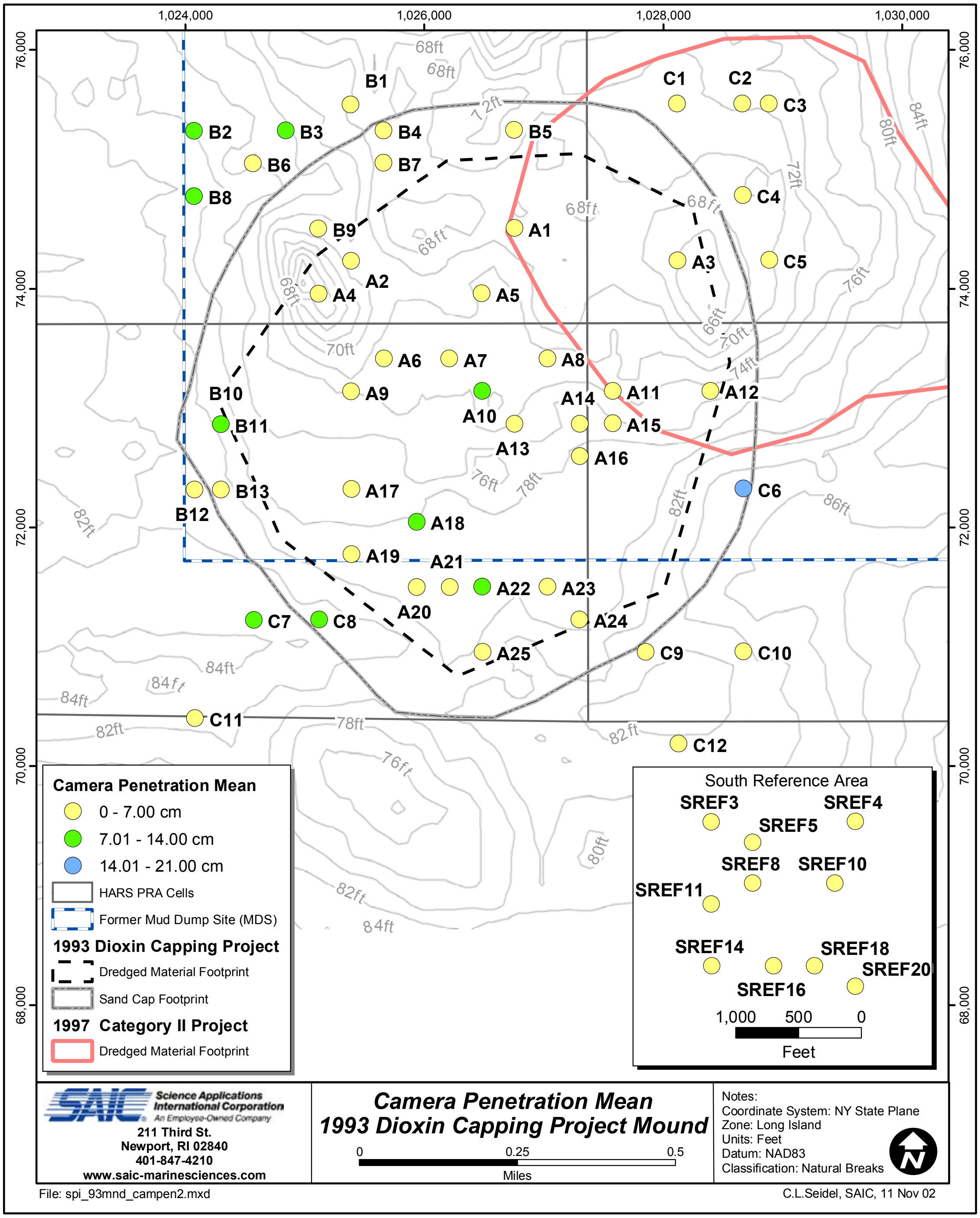


Figure 4.4-9. Map of average camera prism penetration depth values (cm) at the 2002 REMOTS stations

placed on historic dredged material during capping operations. Apparent hard bottom conditions (cobble and rock) at Station B10 resulted in substantially lower camera penetration depths and prevented the analysis of key parameters (e.g., aRPD, successional status, and OSI).

Mean camera prism penetration measurements at the South Reference Area ranged from 4.3 cm at Station SREF10 to 6.3 cm at Station SREF5 (Table 4.4-4 and Figure 4.4-9). The overall average of 5.4 cm was similar to the values observed within Areas A, B, and C and is indicative of relatively firm sediment (sand). Most of the higher penetration values were found in the northeast corner of the South Reference Area; the camera penetration was surprisingly high at SREF3 where benthic habitat SA.M was observed. No other consistent patterns or gradients in penetration depth were apparent within the sandy sediments of the South Reference Area.

4.4.1.4 Boundary Roughness

Small-scale boundary roughness values for stations within Area A ranged from 0.6 cm at Station A10 to 3.4 cm at Station A9, with an overall average of 2.0 cm (Table 4.4-1 and Figure 4.4-10). Values in this range reflect a moderate amount of small-scale surface relief due primarily to physical processes. Surface roughness at Area A stations was attributed to physical factors at all but two replicate images as a result of bedforms (sand ripples) at the sediment-water interface (Figures 4.4-11 and 4.4-2). The well-sorted fine sand observed at the sediment surface throughout the capped area exhibited ripples which were typically a few centimeters in height. The widespread presence of ripples suggests that these sands are subject to bed-load transport, occurring primarily as a result of wave-induced bottom scour during high-energy storm events.

Due to the ubiquitous presence of sand ripples, the capped area (Area A) generally had higher small-scale boundary roughness than surrounding areas (Areas B and C), where more of the stations located outside the cap footprint were characterized by fine-grained sediments.

Small-scale boundary roughness values at Area B ranged from 0.6 cm to 2.7 cm, with an overall average of 1.3 cm indicative of only minor small-scale surface relief (Table 4.4-2 and Figure 4.4-10). Surface roughness was attributed to physical processes (sand ripples) in all but one replicate image. Area C displayed similar boundary roughness values with a range of 0.4 cm to 4.5 cm (Table 4.4-3 and Figure 4.4-10). The overall average of 1.5 cm was likewise indicative of small-scale surface relief due to physical processes in all replicate images. An anomalously high boundary roughness value of 4.5 cm at Station C3, positioned within the slightly coarser sand cap material of the 1997 Dioxin Mound, was related to the presence of large sand ripples in both of the replicate images from this station. Coarser grained sediment (medium sand) is expected to form larger amplitude ripples compared with finer sand. In addition, numerous amphipod stalks were present at the sediment surface of many stations within Areas B and C, while solitary hydroids (*Corymorpha pendula*) were detected exclusively at the sediment surface within stations of Area C (Figure 4.4-11).

Small-scale boundary roughness values for the replicate images obtained in the South Reference Area were lower than those calculated for the capping project stations (Areas A, B, and C). Mean boundary roughness values ranged from 0.3 cm at Station SREF4 to 1.7 cm at Station SREF3 (Table 4.4-4 and Figure 4.4-10). The overall average value of 0.8 cm indicates little

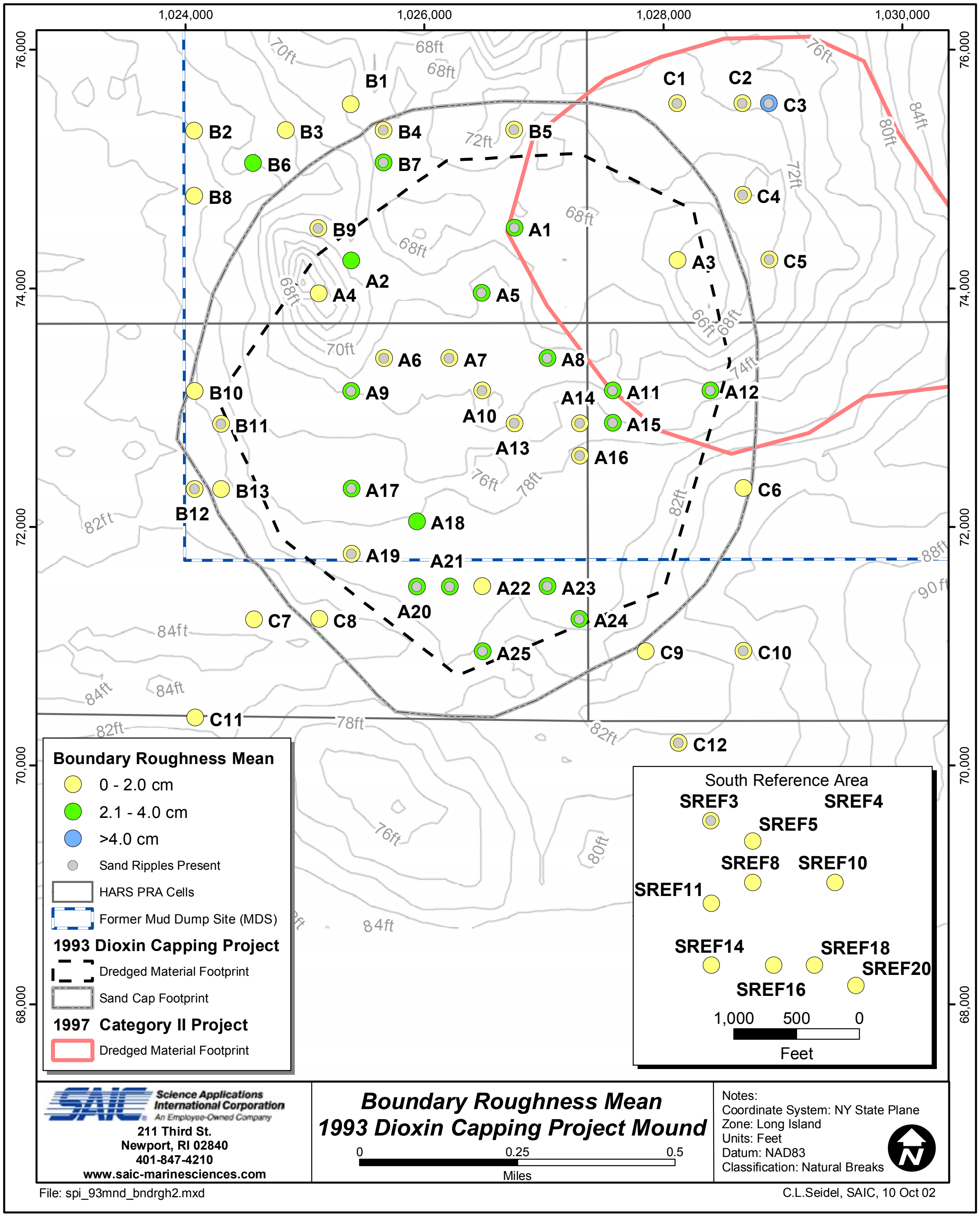


Figure 4.4-10. Map of average boundary roughness (cm) at the 2002 REMOTS stations

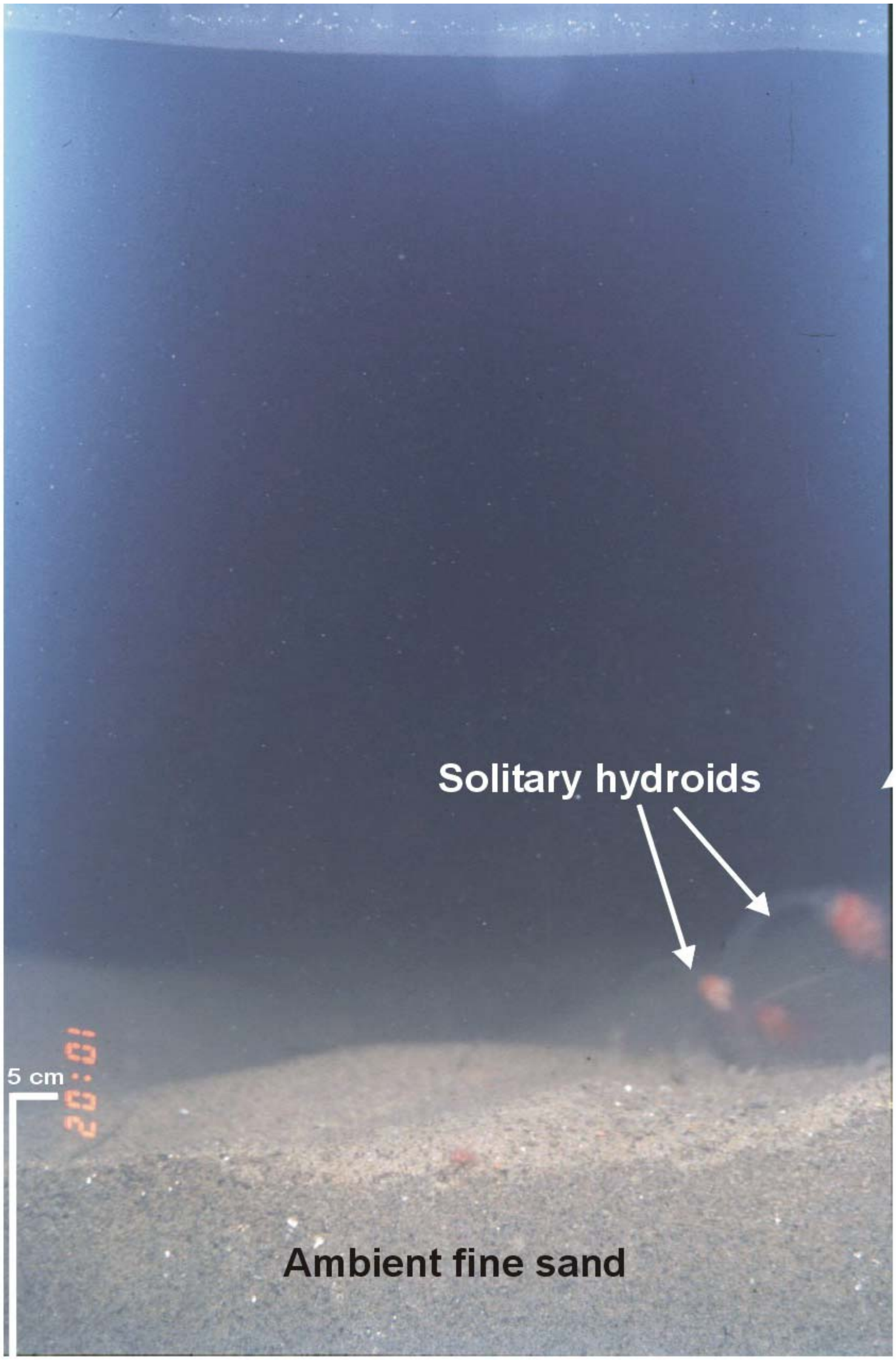


Figure 4.4-11. REMOTS image collected from Station C10 showing solitary hydroids (*Corymorpha pendula*) at the surface of brown ambient sediment

small-scale surface relief. Surface roughness was attributed primarily to physical processes, with the exception of two replicates, which displayed biogenic surface roughness as a result of sand dollars at the sediment-water interface. The high boundary roughness observed at Station SREF3 was the result of sand rippling (sand wave) at the sediment surface; this was the only reference station displaying sand ripples.

The sediment plan view images showed relatively good agreement with the REMOTS images with respect to sediment composition and benthic habitat, and indicated the presence of fine sand over the majority of the surveyed area. Two stations (Stations C6 and S18) did not have an analyzable plan view image due to poor image quality. Sediment plan view images revealed that A stations, within the capping boundary, were dominated by rippled, well-sorted fine and medium grained sands (Figure 4.4-12). Sand ripples were also noted in a number of B and C stations in areas surrounding the capping project. The sediment plan view images supported the results of the REMOTS analysis, showing primarily high reflective surface sediments (sand) and the lesser reflective sediments that typically comprise more fine-grained sediments (i.e., >4 phi) including silts and clay. Consistent with the REMOTS results, reference station SREF3 was the only reference station displaying sand rippling at the surface in the sediment plan view image. Furthermore, a significant amount of shell material was detected in the plan view images throughout the surveyed area (Figure 4.4-12).

There was some small-scale variability at Station A4 positioned near the outer edge of the dredged material footprint due to an existing rock outcrop. The REMOTS image obtained from this station showed homogenous sand cap material, while the plan view image displayed a hard cobble bottom (Figure 4.4-13). Likewise, sediment plan view images at Stations B3 and B6 showed cobbles and pebbles, respectively, while REMOTS images indicated that silty sediment (ambient or relic dredged material) existed at these stations. This discrepancy indicates variability in sediment in the northwestern portion of the survey area just beyond the sand cap footprint due to existing topographic features in that area (Figure 4.4-14).

A number of biological features were detected within the sediment plan view images including starfish, infaunal burrows, polychaete tubes, fecal casts/mounds, solitary hydroids (*Corymorpha pendula)*, flounder, and sand dollars (*Echinarachnius parma*) (Figure 4.4-15). Infaunal burrows and polychaetes tubes were more prevalent among Area A stations, while sand dollars, often in dense aggregations, were more commonly found within the South Reference Area (Figure 4.4-16). These organisms often appeared in the corresponding REMOTS image (Figure 4.4-11).

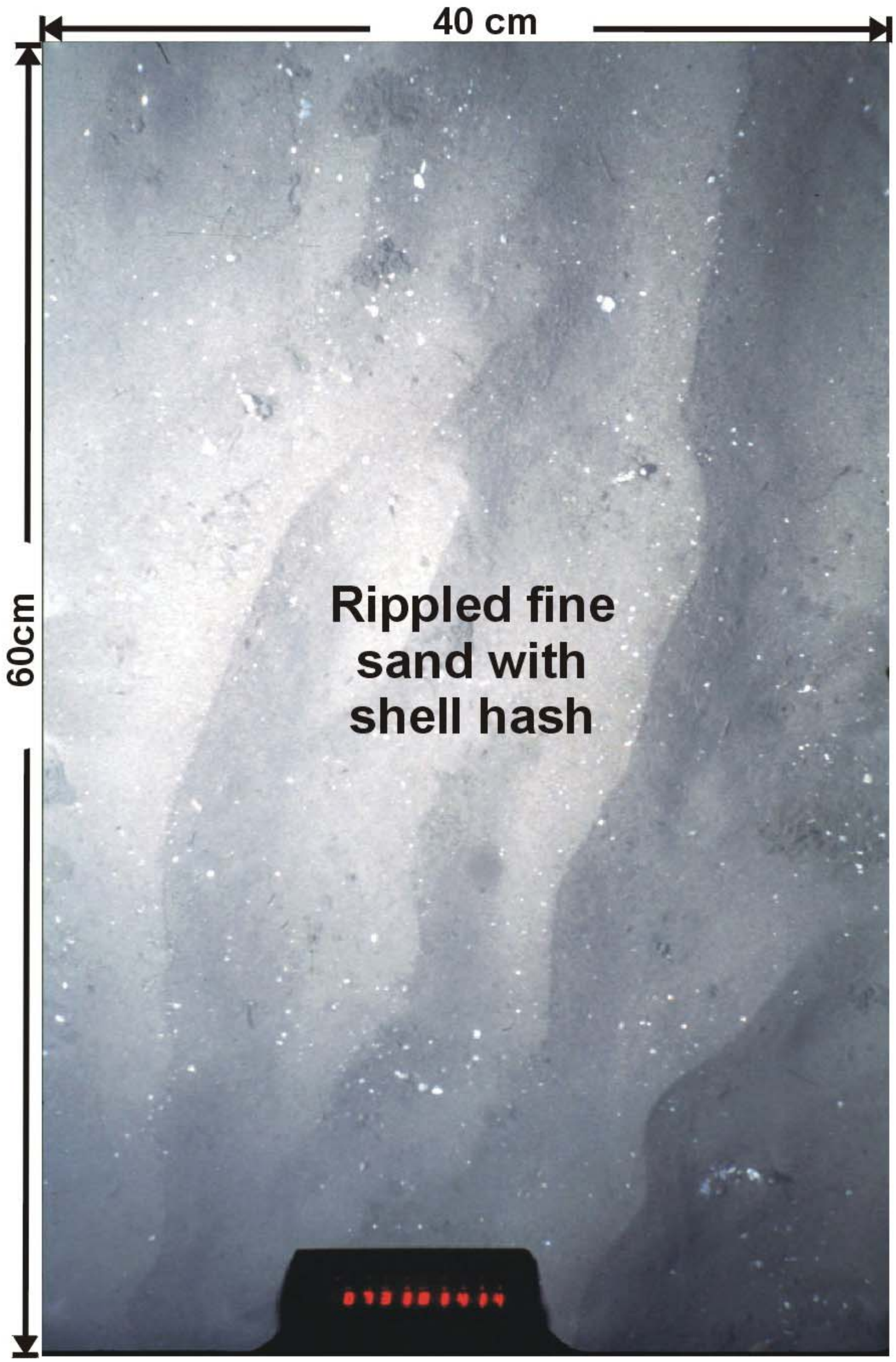


Figure 4.4-12. Sediment plan view image from Station A8 showing the rippled, fine sand characterizing the cap material. Considerable amounts of shell hash are visible in this image.

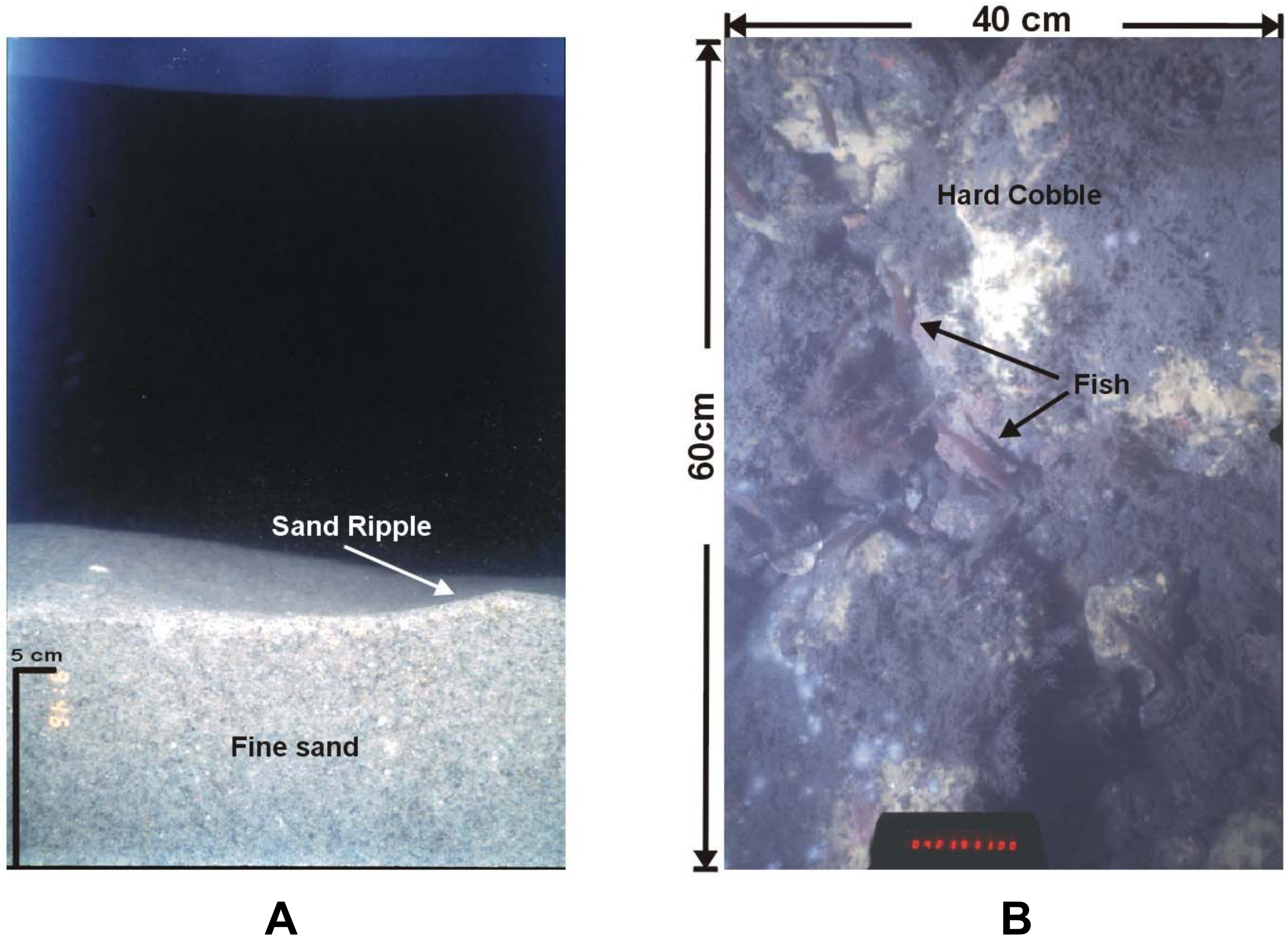
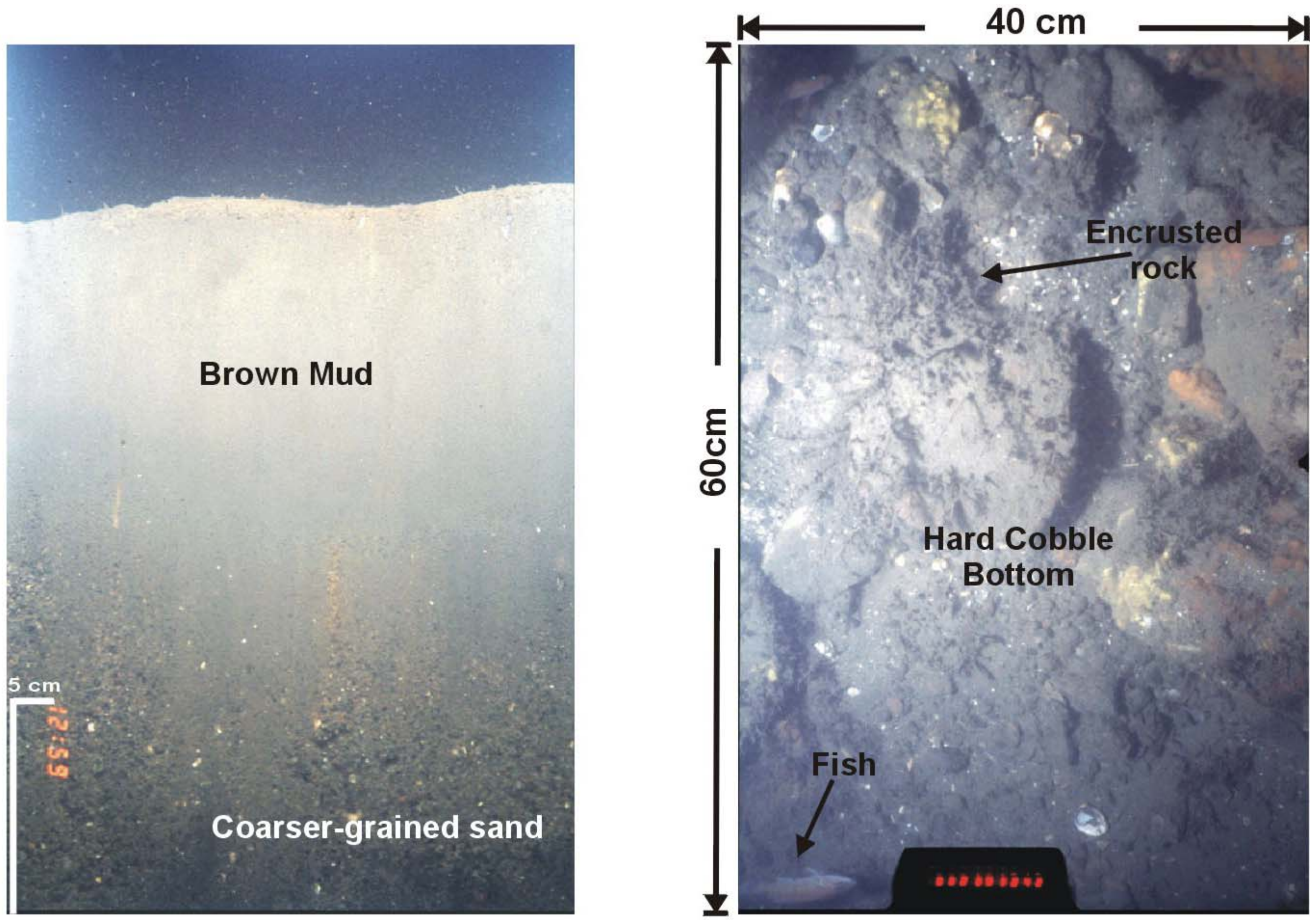


Figure 4.4-13. REMOTS image (A) and corresponding plan view image (B) from Station A4 illustrating variability in sediment composition at this station. The REMOTS image (A) shows a rippled fine sand bottom, while the plan view image (B) displays a hard cobble bottom resulting from past disposal activity in the area. Small fish are visible above the encrusted rocks in the plan view image.



A B

Figure 4.4-14. REMOTS image (A) and corresponding plan view image (B) from Station B3, positioned outside the cap footprint, showing fine-grained material (A) and a hard, cobble bottom (B) within the same station

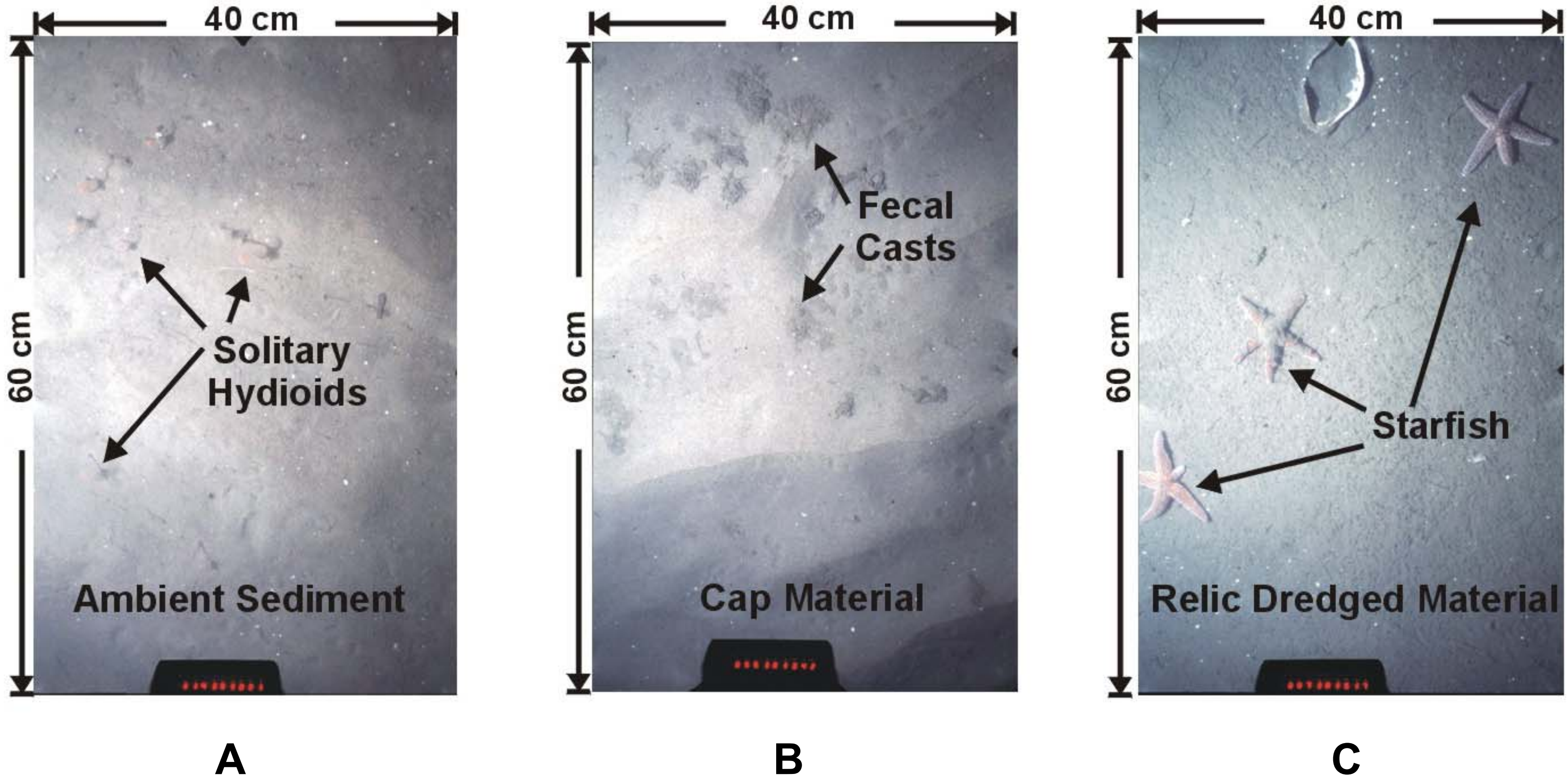


Figure 4.4-15. Sediment plan view images from Station C10 (A), A14 (B), and C8 (C) illustrating a number of biological features present at the sediment surface of various types of sediment. Solitary hydroids are visible at the ambient sediment surface of Station C10 (A), while fecal casts/mounds are visible at the rippled sand cap surface of Station A14 (B). Starfish are present at the surface of relic dredged material at Station C8 (C)

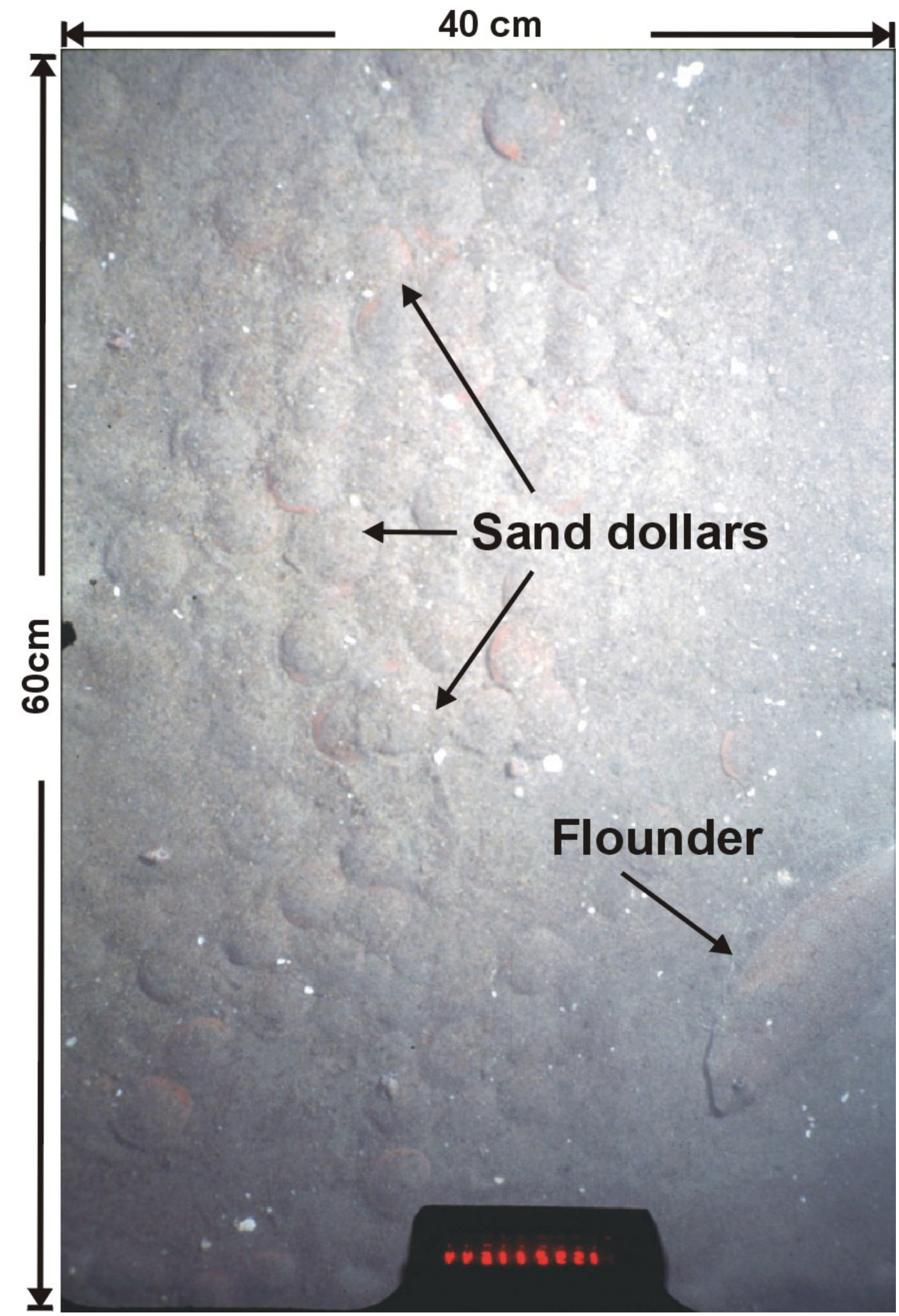


Figure 4.4-16. Sediment plan view image from South Reference Area Station SREF5 showing a dense aggregation of sand dollars at the sediment surface. A flounder is also visible at the surface.

4.4.2 Biological Conditions and Benthic Recolonization

Three REMOTS parameters were used to assess overall benthic habitat quality within the survey area: aRPD depth, infaunal successional status, and Organism-Sediment Index (OSI).

4.4.2.1 Infaunal Successional Stages

Stage I consisting of small, surface-dwelling, opportunistic organisms was the dominant infaunal successional stage observed at the A Stations across the surface of the sand cap (Figure 4.4-17). Seventy-six percent (76%) of the A Stations had Stage I as the highest infaunal successional stage; a combination of Stage I and Stage II was found at the other 24% of the A Stations (Figure 4.4-17; Table 4.4-1). The Stage II organisms consisted of amphipods of the Family Podoceridae which build stalks or stick-like structures that protrude several centimeters above the sediment surface. These stalked amphipods were detected at five stations located in the southern and outer portions of the sand cap footprint (Figures 4.4-17). The amphipod stalks, which often had the amphipods themselves clinging to them, were visible at the surface of all these stations (Figures 4.4-3 and 4.4-18). Evidence of Stage III head-down, deposit-feeding infauna (active feeding voids in the subsurface sediments) was detected along with Stage II amphipods in one replicate image of Station A22 (Stage II on III successional status; Figure 4.4-3). The minimal presence of deeper burrowing infauna (Stage III) was anticipated due to the sandy nature of the cap material and its limitations on burrowing and feeding by Stage III organisms.

Stage I successional status also dominated stations within Area B, however, Stage II and Stage III taxa were also present at these stations (Table 4.4-2 and Figure 4.4-17). Stage II and Stage III were limited to 4 of the 13 stations (31%) in Area B (Stations B8, B9, B11, and B13), located at the outer edges or just outside the capped area mostly within finer-grained relic dredged material (Figure 4.4-17).

A combination of successional stages was observed within Area C, including Stage I pioneering polychaetes, Stage II infaunal amphipods or shallow-dwelling bivalves (*Nucula* sp.), and Stage III head-down deposit feeding infauna. Stage I occurred alone at 6 of the 12 stations (50%), with Stage II or Stage III organisms present at the remaining 6 stations (Table 4.4-3 and Figure 4.4-8). Stage III taxa was present at stations positioned at or beyond the sand cap footprint, generally in areas characterized by fine-grained, relic dredged material (Figure 4.4-17). When present, Stage III taxa were consistently accompanied by either Stage I polychaetes or Stage II infaunal amphipods or shallow-dwelling bivalves at the sediment-water interface (Figure 4.4-19).

The successional status at the South Reference Area included principally Stage I surface-dwelling, opportunistic polychaetes at all stations (Table 4.4-4 and Figure 4.4-17). The dominance of sand and the absence of organic-rich, fine-grained sediment at the South Reference Area precludes the establishment of a Stage III community consisting of subsurface deposit feeders.

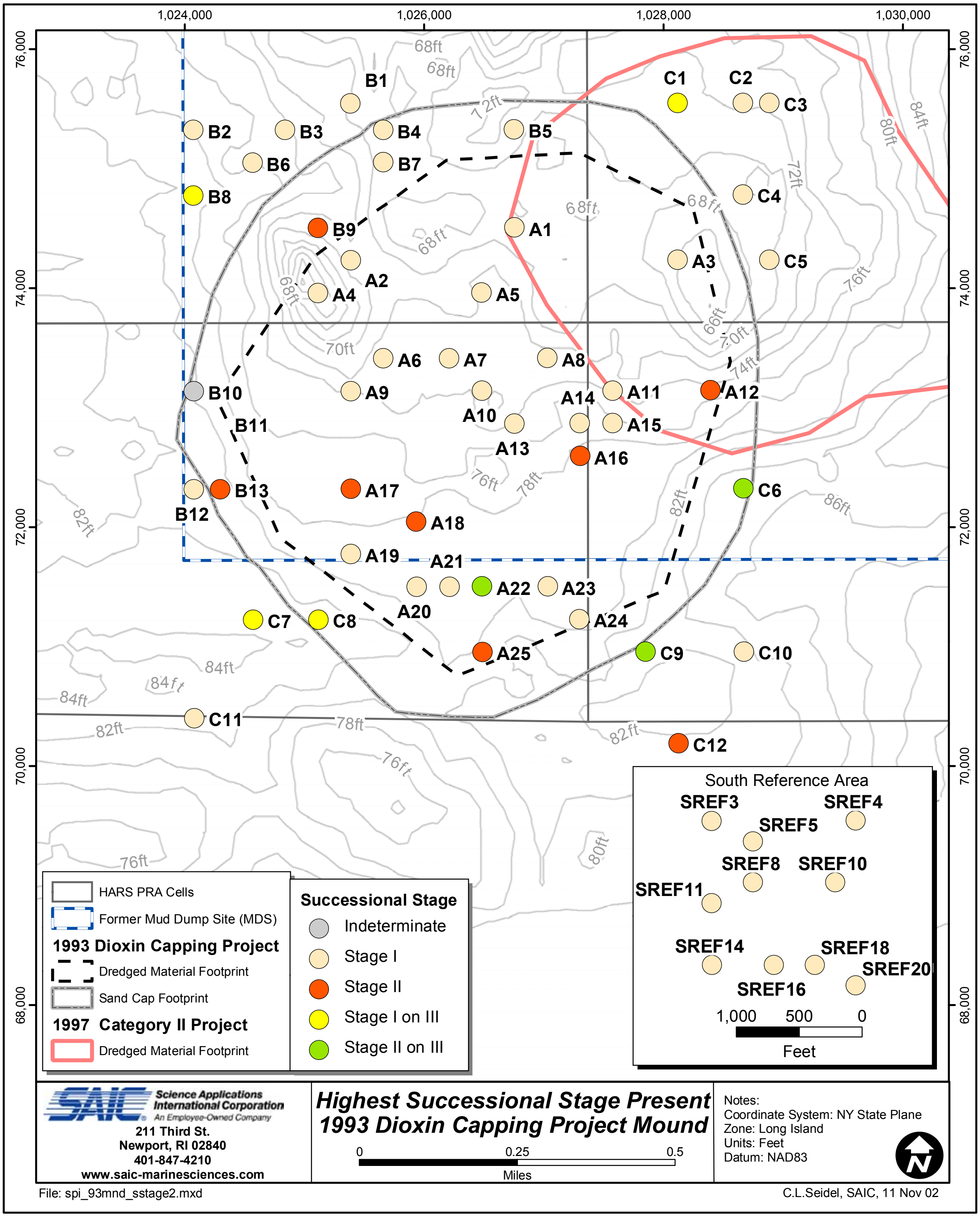


Figure 4.4-17. Map showing the highest infaunal successional stage present at each of the 2002 REMOTS stations

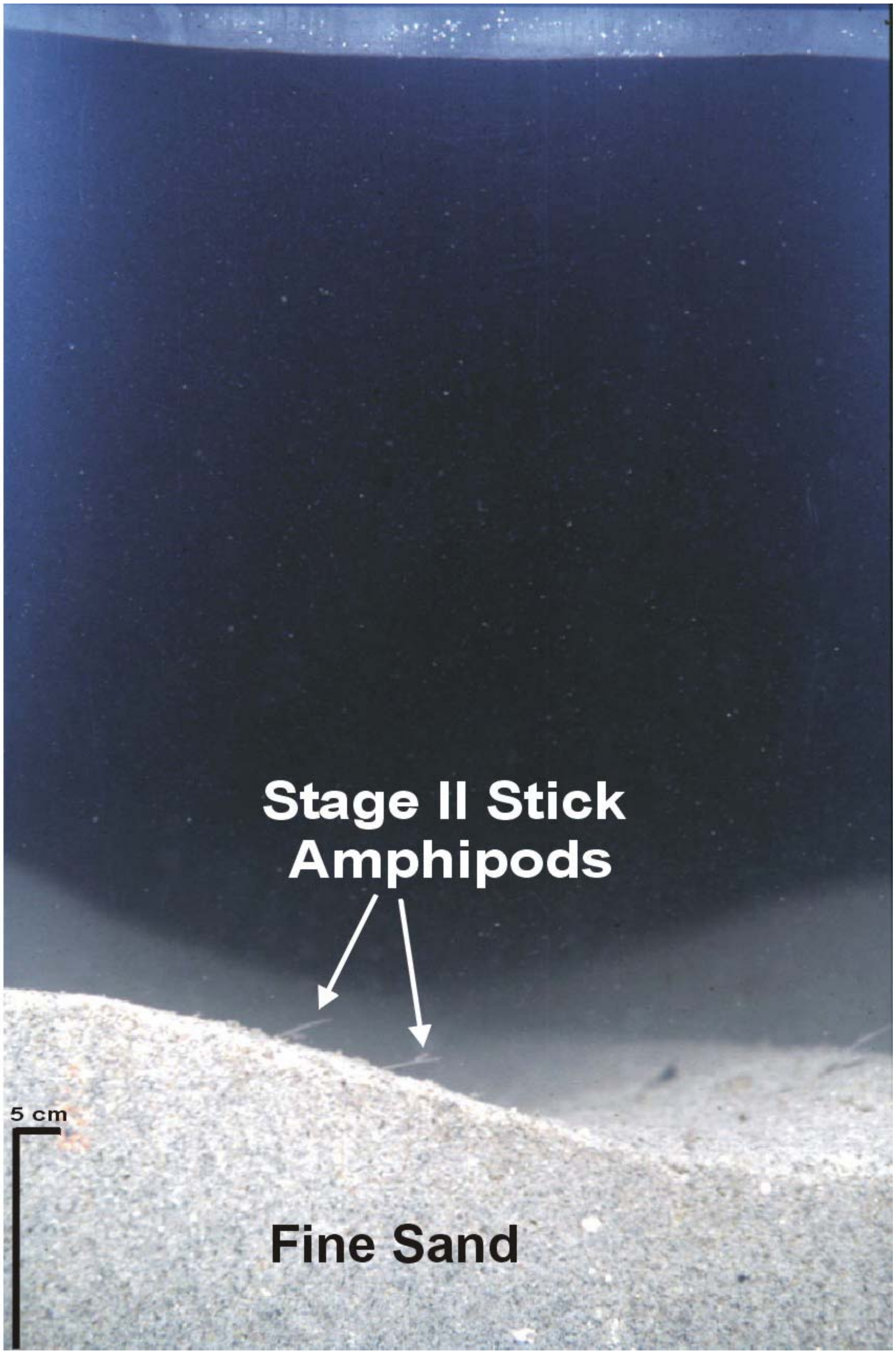


Figure 4.4-18. REMOTS image from Station A25 showing Stage II stick amphipods at the surface of sand cap material

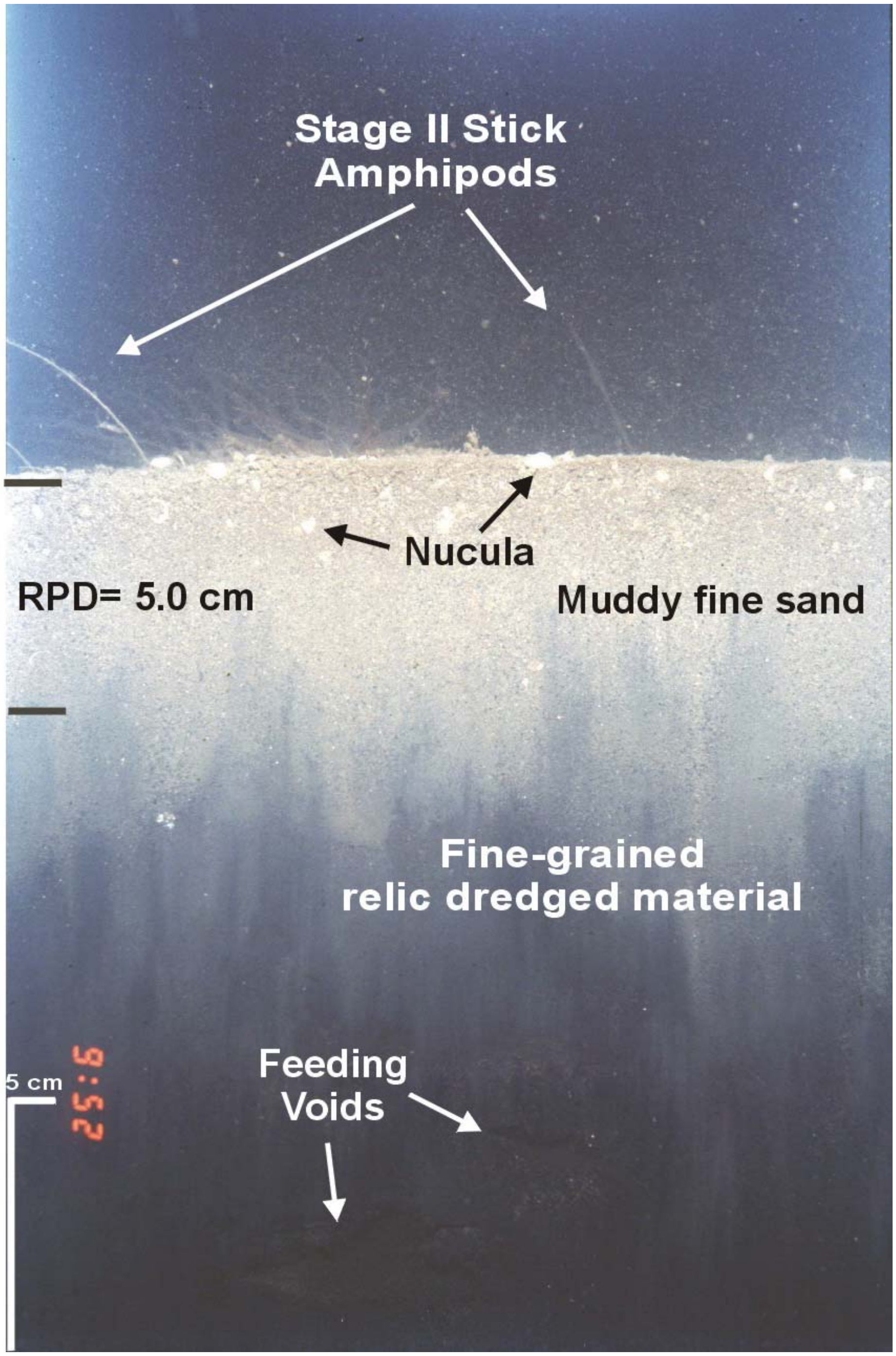


Figure 4.4-19. REMOTS image from Station C6 illustrating Stage II stick amphipods and shallow-dwelling bivalves (*Nucula*) at the sediment surface over Stage III feeding voids in the subsurface sediments (Stage II on III successional status). A well-developed aRPD depth of 5 cm and the advanced successional status resulted in an OSI value of +9 for this image, indicative of undisturbed benthic habitat quality.

4.4.2.2 Apparent Redox Potential Discontinuity Depths

The aRPD depth provides a measure of the apparent depth of oxygen penetration into the surface sediments and the degree of biogenic sediment mixing. The mean aRPD depths at Area A stations ranged from 1.3 cm at Station A16 to > 6.5 cm at Station A4, with an overall average of 3.9 cm (Table 4.4-1 and Figure 4.4-20). Mean aRPD depths were similar among Area B and C stations. Mean aRPD measurements ranged from 2.2 cm to > 4.2 cm at Area B and from 1.6 cm to > 5.7 cm at Area C, with overall averages of 3.3 cm and 3.4 cm, respectively (Tables 4.4-2 and 4.4-3; Figure 4.4-20). Overall, these are relatively deep aRPD depths, which are indicative of well-oxygenated surface sediments. At the sandy stations, this oxidation is attributed to physical mixing of the uppermost sediment layer related to periodic bedload movement of the sand. At stations characterized by fine-grained relic dredged material (portions of Areas B and C), aeration of the sediment and corresponding increases in the aRPD depth are attributed to bioturbation activities of infaunal organisms. The deepest mean aRPD depths occurred at stations characterized by high reflectant sand cap material and therefore, the aRPD depths were a function of the camera prism penetration depth (i.e., aRPD > penetration). These aRPD depths measured beyond camera prism penetration represent a minimum measurement and are considered conservative estimates of sediment oxygenation at these sandy stations. When values greater than camera penetration are not considered, aRPD depths generally fell between 2 and 4 cm over the entire survey area.

The mean aRPD depths at stations within the South Reference Area were comparable to those observed within the 1993 Dioxin Mound Area, ranging from 2.9 cm at Station SREF16 to > 6.3 cm at Station SREF5 (Table 4.4-4 and Figure 4.4-20). The overall average of 4.5 cm is indicative of well-oxygenated surface sediments. Like the sand cap area, aRPD depths at the reference area is primarily controlled by physical movement of the seabed by sand waves. Furthermore, aRPD depths extended beyond the penetration depth of the camera prism at the majority of these sandy stations (i.e., aRPD > penetration). Like the 1993 Dioxin Mound stations, these are conservative measurements (Figure 4.4-6).

4.4.2.3 Organism-Sediment Index

Mean OSI values for Area A stations ranged from +3.5 at Station A16 to +7.5 at Station A25 (Table 4.4-1 and Figure 4.4-21). The overall value of +6.1 is generally indicative of undisturbed or non-degraded benthic habitat conditions. Of the 25 stations, 15 stations displayed mean OSI values > +6 (highly colonized or undisturbed). At the sand cap stations (Area A), the relatively high values mainly reflect deep mean aRPD depths and widespread presence of Stage I organisms.

Similarly, mean OSI values at Area B stations ranged from +4.0 at Station B6 to +8.0 at Station B8, with an overall average of +6.0 (Table 4.4-2 and Figure 4.4-21). Despite the minimal presence of advanced Stage III organisms, these OSI values are indicative of undisturbed benthic habitat quality and principally reflect well-developed aRPD depths. However, the highest OSI values were found at Area C stations located on either older, uncapped dredged material, cap sand over relic dredged material, or ambient sediment. No apparent spatial trends in mean OSI values were noted in Area C stations. Mean OSI values at C stations ranged from +4.5 at

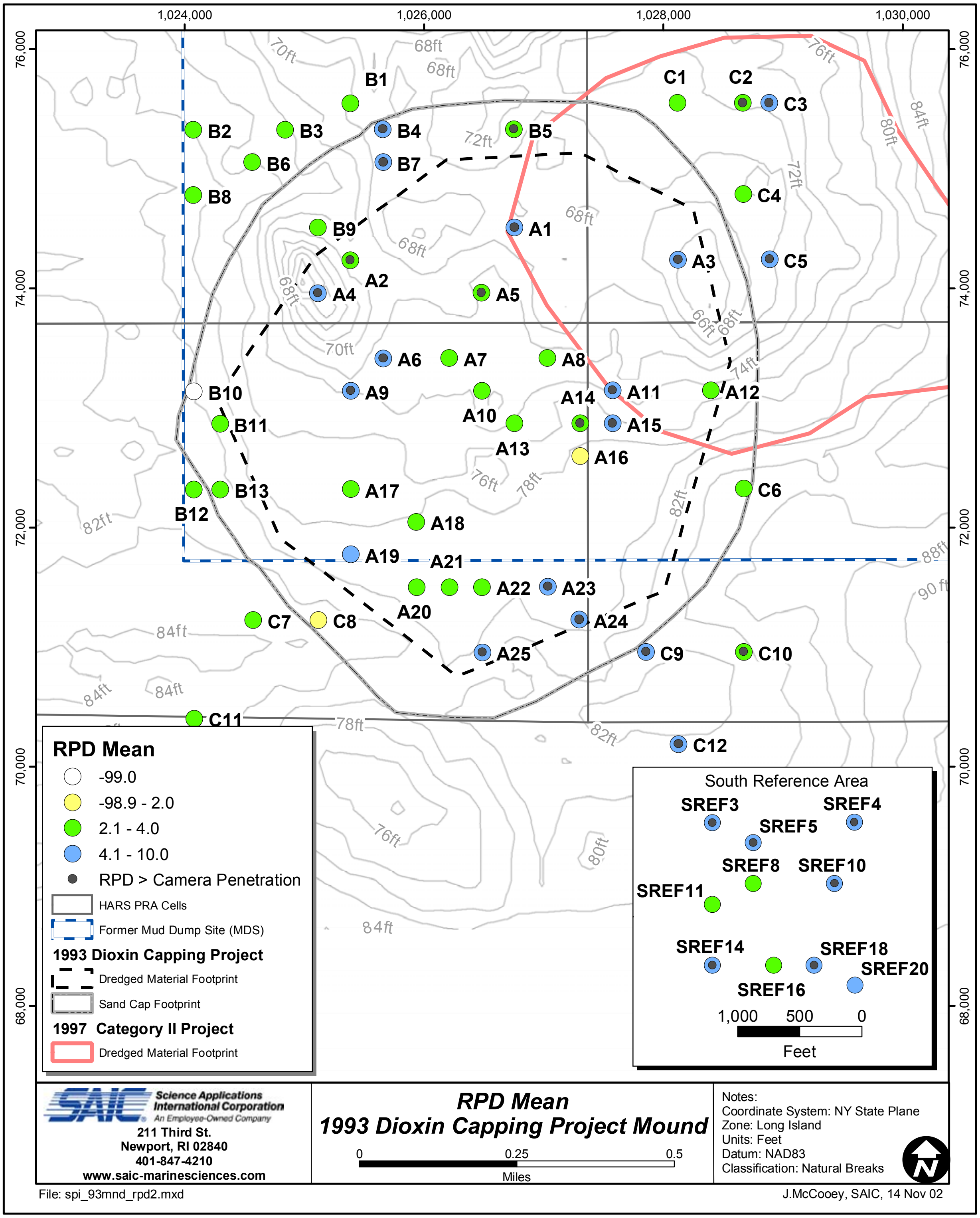


Figure 4.4-20. Average aRPD depths (cm) at the 2002 REMOTS stations over the 1993 Dioxin Capping Project Area

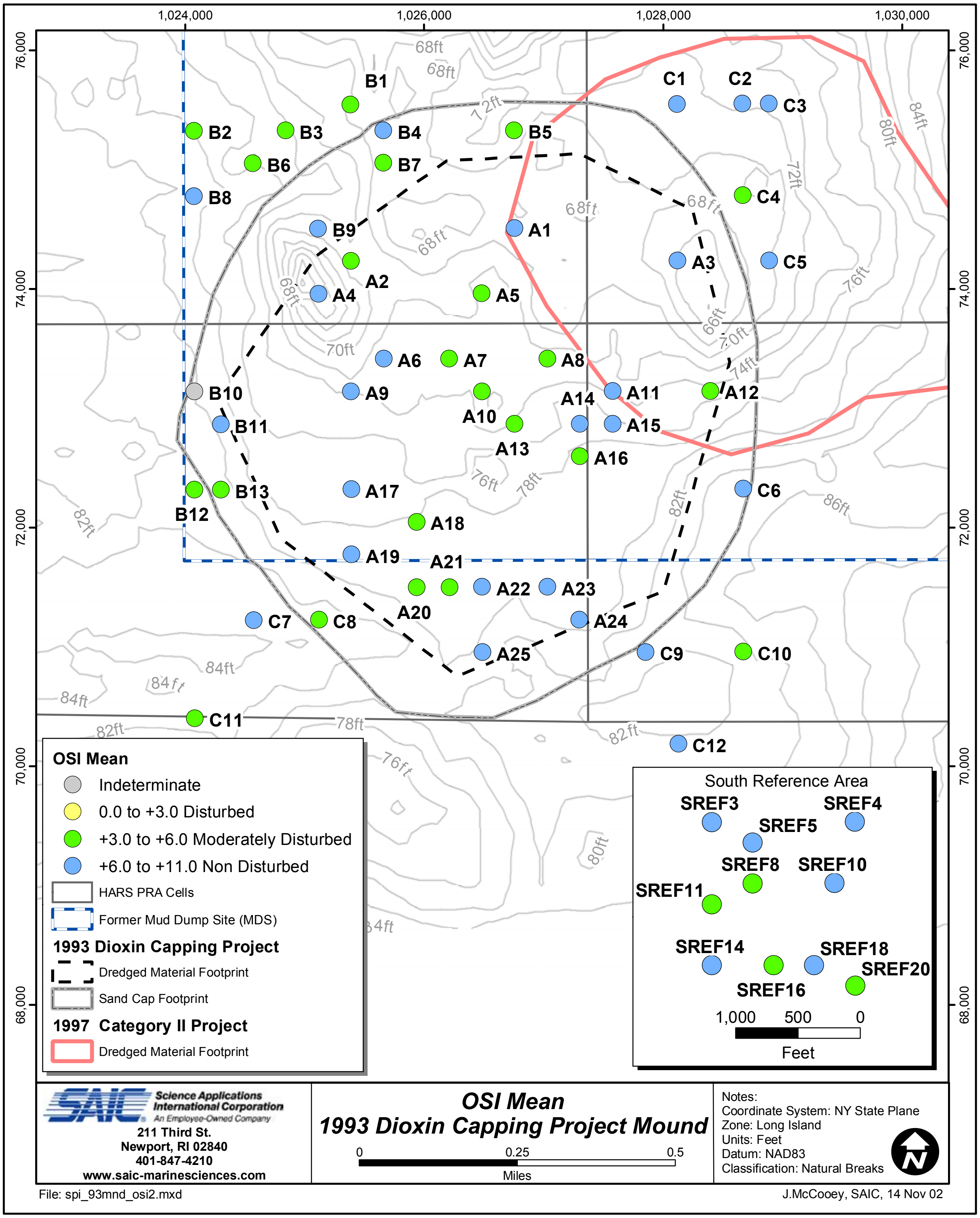


Figure 4.4-21. Average OSI values at the 2002 REMOTS stations over the 1993 Dioxin Capping Project Area

Station C11 to +11.0 at Station C9 (Table 4.4-3 and Figure 4.4-21). The overall OSI average of +7.2 is indicative of non-degraded or undisturbed benthic habitat quality (OSI values > +6). These stations (Area C) had a combination of relatively deep aRPD depths and a higher frequency of advanced Stage I on III or Stage II on III infaunal assemblages (e.g., Figure 4.4-19).

Benthic habitat quality at the South Reference Area was comparable to the capping project stations within Areas A, B, and C. Mean OSI values ranged from +5.5 at Stations SREF16 and SREF8 to +7.0 at Stations SREF3, SREF5, SREF10, SREF14, and SREF 18, with an overall average of +6.5 (Table 4.4-4 and Figure 4.4-21). The overall OSI value (+6.5) is indicative of undisturbed benthic habitat conditions. These relatively high OSI values reflect relatively deep (> 3 cm) aRPD depths and the widespread presence of Stage I organisms.

4.5 Benthic Grab Sampling

4.5.1 1993 Dioxin Mound

A complete set of data showing all of the benthic taxa collected at the 1993 Dioxin Mound and South Reference Area stations is provided in Appendix B. Fine sand was the dominant grain size fraction in the grab samples collected at the 1993 Dioxin Mound stations, ranging from 71% at Station A-19 to 95% at Station A-5 (Table 4.5-1). Stations A-9 and A-19 had higher proportions of medium sand (range 17% to 23%) compared to the other three mound stations (range 1.5% to 5.3%), while Station B-8 had proportionately more silt-clay (Table 4.5-1). The amount of coarse sand and gravel (combined) was minimal at the five stations, ranging from less than 2% at Stations A-5, A-9, A-10 and A-23 to less than 3.5% at Station B-8.

Overall, a total of 59,500 individuals/m^2 belonging to 80 unique taxa were collected in the five grab samples over the 1993 Dioxin Mound. However, organism density varied widely among the five stations, ranging from 2,150 individuals/m^2 at Station A-9 to 31,025 individuals/m^2 at Station B-8, while the number of taxa found at each station ranged from 27 to 38 (Table 4.5-2). The large among-station variation in organism density was due primarily to differences in the numbers of the nut clam, *Nucula proxima*. Overall, this species was the overwhelming numerical dominant across the 1993 Dioxin Mound, accounting for 71% of the total number of individuals collected at the five stations (Table 4.5-2). However, the density of this species at each station varied widely, from 25 individuals/m^2 at Station A-9 to 24,850 individuals/m^2 at Station B-8 (Table 4.5-2). *Nucula proxima* is a common Stage II species that is relatively insensitive to sediment contamination and has been reported as one of the basic, dominant infauna of the New York Bight (Chang et al. 1992).

Among the other numerical dominants across the 1993 Dioxin Mound were a significant number of annelids, including the Stage I polychaetes *Polygordius* sp., *Monticellina dorsobranchialis*, and *Exogone hebes*, the Stage III polychaetes *Aricidea catherinae*, *Scoletoma* sp., and *Nepthys picta*, and Stage I oligochaetes belonging to the Family Tubificidae (Table 4.5-2). Several arthropods were also relatively abundant, including the ostracod *Pellucistoma* sp., the cumaceans *Diastylis polita* and *Mancocuma stellifera*, the isopod *Edotea triloba* and the amphipod *Dulichia porrecta*. Finally, the bivalve molluscs *Tellina agilis* (dwarf Tellin) and *Pita morrhuanas* (false quahog) also were among the top 15 most abundant taxa (Table 4.5-2).

Table 4.5-1.
Summary of Grain Size Analysis Results for the Benthic Grab Samples

	% Medium Sand	% Fine Sand	% Silt-clay
93 Mound Stations			
A-5	1.5	95.2	3.3
A-9	16.8	79.8	3.3
A-19	23.1	70.6	5.2
A-23	1.6	94.8	3.5
B-8	5.3	76.8	14.6
South Reference Area Stations			
S-4	50.2	46.4	2.7
S-8	19.7	75.7	4.4
S-14	9.5	88.8	1.7

Table 4.5-2.
Summary of Benthic Community Parameters for the 1993 Dioxin Mound Stations

	Station				
	A-19	A-23	A-5	A-9	B-8
No. individuals/m^2	2,350	14,250	9,725	2,150	31,025
No. of taxa	27	38	33	27	37
Shannon-Weiner diversity (log-e)	2.53	1.18	1.92	2.94	1.10
Margelef's species richness	3.35	3.87	3.48	3.39	3.48
Pielou's evenness	0.77	0.31	0.55	0.89	0.31
Fifteen most abundant taxa for all 5 stations combined (percent of total abundance in parentheses)	Nucula proxima (71%) Pullucistoma (LPIL) (4%) Aricidea catherinae (2%) Scoletoma (LPIL) (2%) Polygordius (LPIL) (2%) Monticellina dorsobranchialis (2%) Diastylis polita (1%) Nepthys picta (1%) Exogone hebes (1%) Edotea triloba (1%) Pita morrhaunus (1%) Mancocuma stellifera (1%) Tellina agilis (1%) Dulichia porrecta (1%) Tubificidae (LPIL) (1%)				

Shannon-Weiner diversity (H') and Pielou's evenness were both relatively low at Stations A-23 and B-8, reflecting the disproportionately high numbers of *Nucula proxima* found at these two stations compared to the other three 1993 Dioxin Mound stations (Table 4.5-2). Species richness did not vary as widely among the five stations, ranging from 3.35 to 3.87.

4.5.2 South Reference Area

The grain size distribution at South Reference Stations S-8 and S-14 was generally similar; both were dominated by fine sand, with a moderate proportion of medium sand (10% to 20%) and less than 5% silt-clay (Table 4.5-1). At Station S-4, medium sand was the dominant fraction at slightly more than 50%, followed by a significant fine sand fraction (46%) and less than 3% silt-clay (Table 4.5-1). The combined proportions of coarse sand and gravel were less than 1% at all three South Reference stations.

Overall, a total of 11,550 individuals/m^2 belonging to 60 unique taxa were collected at the three South Reference Area stations. Organism density did not vary as widely among the three South Reference Area stations as it did among the 1993 Dioxin Mound stations, ranging from 2,400 individuals/m^2 at Station S-8 to 5,625 individuals/m^2 at Station S-14 (Table 4.5-3). The number of unique taxa found at each station ranged from 28 to 38. The most numerically abundant organisms at the three reference stations were Tubificid oligochaetes, which accounted for 16% of the total overall number of individuals (Table 4.5-3). These are generally considered pollution-tolerant, opportunistic Stage I organisms.

Among the other numerical dominants at the South Reference Area were several annelids, including the Stage I polychaetes *Polygordius* sp., *Monticellina dorsobranchialis*, *Exogone hebes*, and *Caulleriella* sp. J, as well as the Stage III polychaetes *Aricidea catherinae* and *Nepthys picta* (Table 4.5-3). Several arthropods were also relatively abundant, including the ostracod *Pellucistoma* sp., the cumacean *Mancocuma stellifera*, the isopod *Chiridotea tuftsi*, the tanaid *Tanaissus psammophilus*, and the amphipods *Rhepoxynius epistomus* and *Unciola* sp. The nut clam *Nucula proxima* was also among the top 15 most abundant taxa, but at significantly lower densities than observed over the 1993 Dioxin Mound (Table 4.5-3).

Shannon-Weiner diversity (H') ranged from 2.53 to 3.23 and Pielou's evenness ranged from 0.76 to 0.89 at the three reference area stations (Table 4.5-3). Reflecting the relatively high number of taxa found at Station S-4, this station had the highest species richness among the three.

4.5.3 Comparison of 1993 Dioxin Mound and South Reference Stations

4.5.3.1 Univariate Statistics

The average organism density per station over the 1993 Dioxin Mound (11,900 individuals/m^2) was considerably higher than at South Reference (3,850 individuals/m^2; Table 4.5-4). This difference is due largely to the disproportionately high numbers *Nucula proxima* at several of the 1993 Dioxin Mound stations. The uneven distribution of this species among the five 1993 Dioxin Mound stations is reflected in the high standard deviation of ±11,856 individuals/m^2 (Table 4.5-4). The 1993 Dioxin Mound and the South Reference Area had an equal average

Table 4.5-3.
Summary of Benthic Community Parameters
for the South Reference Area Stations

	Station S-4	 S-8	 S-14
No. individuals/m2	3,525	2,400	5,625
No. of taxa	38	30	28
Shannon-Weiner diversity	3.23	2.93	2.53
Margelef's species richness	4.53	3.73	3.13
Pielou's evenness	0.89	0.86	0.76
Fifteen most abundant taxa for all 3 stations combined (percent of total abundance in parentheses)	Tubificidae (LPIL) (16%) Exogone hebes (LPIL) (10%) Polygordius (LPIL) (8%) Pellucistoma (LPIL) (8%) Nepthys picta (6%) Mancocuma stellifera (4%) Caulleriella sp. J (4%) Aricidea catherinae (3%) Rhepoxynius epistomus (3%) Rhynchocoela (LPIL) (2%) Tanaissus psammophilus (2%) Monticellina dorsobranchialis (2%) Nucula proxima (2%) Unciola (LPIL) (2%) Chiridotea tuftsi (2%)		

Table 4.5-4.
Comparison of Benthic Community Anaylsis Results for the
1993 Dioxin Mound versus the South Reference Area Stations

	1993 Dioxin Mound	South Reference Area
Number of stations (samples)	5	3
Avg. no. individuals/m^2 per station (± 1 s.d.)	11,900 (± 11,856)	3,850 (± 1,637)
Avg. no. taxa per station (± 1 s.d.)	32 (± 5)	32 (± 5)
Avg. Shannon-Weiner diversity (± 1 s.d.)	1.92 (± 0.8)	2.9 (± 0.4)
Avg. Pielou's evenness (± 1 s.d.)	0.57 (± 0.26)	0.84 (± 0.07)
Avg. Margelef's species richness (± 1 s.d.)	3.52 (± 0.22)	3.80 (± 0.70)

number of taxa per station (32), but the South Reference Area had higher average diversity, evenness and species richness. These differences are also due to the disproportionately high numbers of *Nucula proxima* at several of the 1993 Dioxin Mound stations.

Several of the numerically dominant taxa at the 1993 Dioxin Mound were also among the dominants at the South Reference Area. This includes the bivalve *Nucula proxima*, the Stage I polychaetes *Exogone hebes*, *Polygordius* sp., and *Monticellina proxima*, the Stage III polychaetes *Nepthys picta* and *Aricidea catherinae*, the ostracod *Pellucistoma* sp., the cumacean *Mancocuma stellifera*, and the tubificid oligochaetes.

4.5.3.2 Multivariate Statistics

In both the cluster analysis dendrogram (Figure 4.5-1) and the two-dimensional nMDS plot (Figure 4.5-2), the following three station groups are identified: 1) Stations B-8, A-23 and A-5, 2) Stations A-19 and A-9, and 3) Stations S-4, S-8 and S-14. The stations falling within each of these groups are considered to have roughly similar benthic community structure (i.e., similar species present in roughly similar numbers), although the degree of similarity among stations within each group and among the three groups was not particularly high. For example, while the three reference area stations had community structure more similar to each other than to any other stations, the Bray-Curtis similarity among these three stations was less than 50% (i.e., note fusing of these three stations at roughly the 45% Bray-Curtis similarity level in Figure 4.5-1).

The benthic community at Stations A-9 and A-19 was more similar to the reference area stations than to the other three 1993 Dioxin Mound stations. These results are partly due to the higher proportion of medium sand at Stations A-9 and A-19, making the habitat at these stations (in terms of sediment grain size) more similar to that at the reference stations than to Stations A-5, A-23 or B-8. Higher relative proportions of finer-grained sediment (i.e., fine sand and silt-clay) occurred in conjunction with disproportionately high numbers of *Nucula proxima* at Stations A-5, A-23 and B-8, which was the main reason that these three stations clustered together and were different from the other two station groups. The ANOSIM test resulted in an R-statistic of 0.43, indicating some overlap but generally different benthic community structure between the 1993 Dioxin Mound and South Reference Area Stations.

4.6 Core Descriptions and Imagery

This section presents descriptions of the cores based on visual observations and photographs. All of the processed cores met the project criteria of a minimum length of six feet (183 cm). Core photographs with detailed descriptions of the sediment type and sampling intervals are provided in Appendix C-1.

The material observed in this suite of cores was classified as either sand cap material or underlying dredged material. The specific characteristics of each of these material units are discussed in detail below. Both the visual observations made by SAIC laboratory technicians, and down-core geotechnical profiles were consulted to arrive at the material type classifications presented.

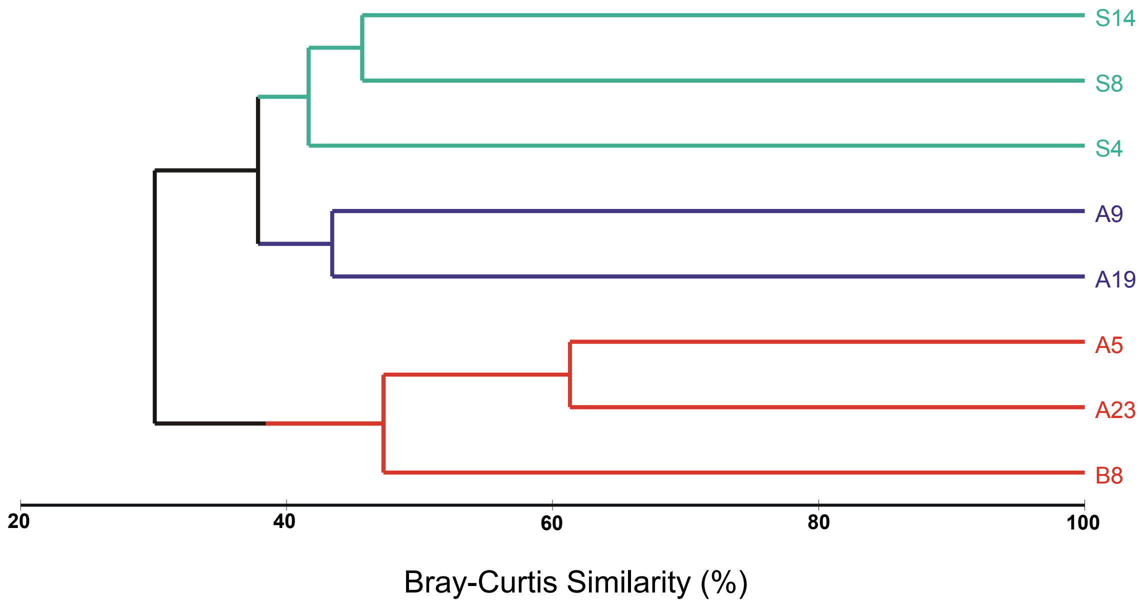


Figure 4.5-1. Dendrogram for hierarchical clustering of the 1993 Dioxin Mound and the South Reference Area stations based on Bray-Curtis similarity. See Figure 2.5-1 for station locations.

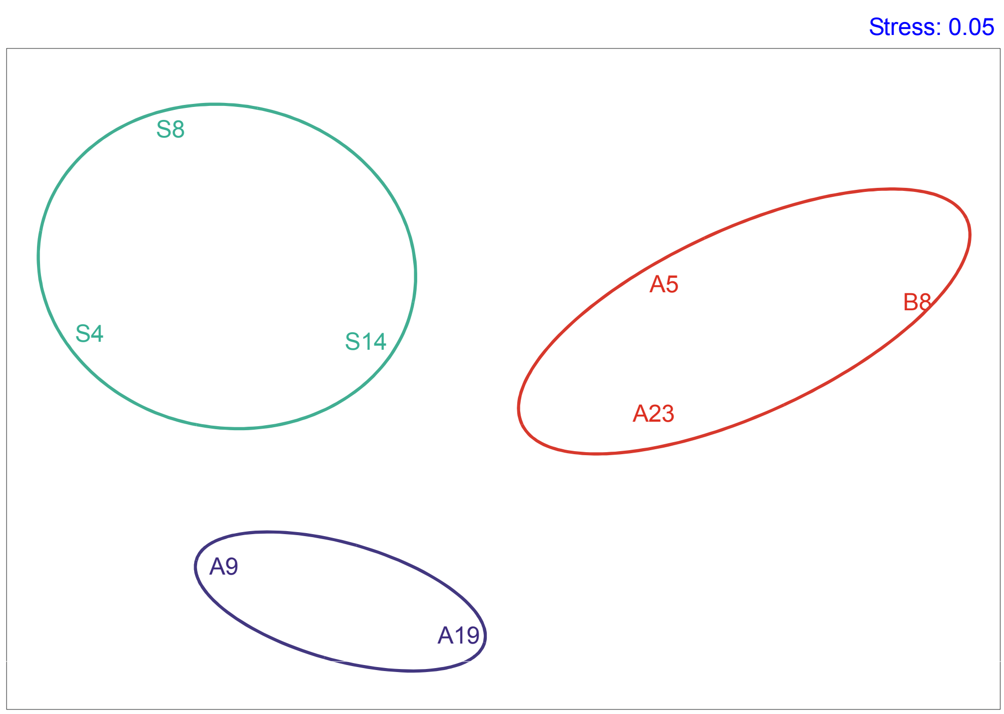


Figure 4.5-2. Two-dimensional nMDS plot of the 1993 Dioxin Mound and the South Reference Area stations based on Bray-Curtis similarity. See Figure 2.5-1 for station locations.

4.6.1 Sand Cap

The sand cap material was a mix of fine to coarse sand that ranged from dark gray to tan in color. The transition between the cap and dredged material units was clearly evident, as seen in the core images (Appendix C-1).

All 14 cores were collected within the cap boundary footprint (Figure 2.7-1). All cores contained a visible sand cap layer. Cap thickness was variable ranging from 50 cm in Core HU to greater than 276 cm in Core GX (Table 4.6-1). Because the core did not penetrate through the cap material into the underlying dredged material at Stations G7 and GX (i.e., only cap material was recovered), the cap thickness measurements at these two stations are indicated with a greater than sign in Table 4.6-1. Excluding these two stations, the overall average sand cap thickness for the 12 remaining cores collected in 2002 was 150 cm (Table 4.6-1). Two cores contained less than 1 m of cap material, G6 and HU. The cap thickness of these cores was similar to the results from the most recent previous coring survey (May 1997) at the same stations (Table 4.6-1). The spatial variability of the cap is illustrated in Cores G6 and HU. Both of these cores were located between stations where cap thickness ranged from 130 to 276 cm.

The 14 coring stations sampled in the 2002 survey were the same as those sampled in previous surveys over the mound. When cap thickness measurements for the 2002 survey are compared to those of the most recent previous survey (May 1997), nine cores indicated either the same or greater cap thickness (G2, G3, G5, G6, G7, GX, H3, HV, and HS). Cap thickness in Cores G4, H2, H4, HU, and HT was less than that measured in 1997 (Table 4.6-1). Previous coring surveys from the 1993 Dioxin Mound have shown similar spatial variability in cap thickness, both among replicate cores and at similar locations through time (SAIC 1995b, 1995c, 1998).

4.6.2 Dredged Material

Overall, the dredged material unit was composed of fine-grained black, brown, or dark gray silty clay material. Large pieces of shell, generally oyster and blue mussel, were present in the dredged material unit in a majority of the collected cores. These observed variations in color and texture are typical of the project-dredged material, as noted in previous surveys (SAIC 1995b, 1995c), and are attributed to its natural variability.

Of the 14 cores collected, only five contained more than 1 m of dredged material, and none penetrated past the dredged material into the ambient seafloor. On average each core contained 92 cm of dredged material, with none present in Cores G7 and GX. The cap thickness layer and the dredged material layer were equally variable in thickness within the core samples. The length of the core and the thickness of the cap material dictate the volume of underlying sediment captured in the cores. The thickest layer of dredged material was noted in Core G6 (241 cm). Because none of the cores were deep enough to penetrate past the dredged material into the underlying ambient sediment, the measurements of dredged material thickness present here represent only conservative estimates of the actual dredged material layer thickness.

Table 4.6-1.
Measured Thickness of the Sand Cap Layer in the 2002 and 1997 Cores

Core Station ID	2002 Total Core Length (cm)	2002 Sand Cap Thickness (cm)	1997 Sand Cap Thickness (cm)
G2	286	230	116
G3	280	258	115
G4	224	142	231
G5	220	117	64
G6	300	59	55
G7	246	>246*	242
GX	276	>276*	88
H2	280	186	235
H3	243	162	90
H4	272	190	192
HU	192	50	75
HV	238	130	106
HT	265	117	128
HS	234	163	124
Average	**254**	**150**	**133**

*Excluded from calculation of the average

Overall the dredged material detected in the sediment vibracores was well consolidated and did not appear to have changed significantly since the previous survey. Red clay was found at the bottom of seven of the cores (G3, G5, G6, H2, HS, HT and HU). The geotechnical parameters of the red clay were unlike the majority of the dredged material and skewed the statistical analysis of samples collected from the majority of the dredged material.

4.7 Geotechnical Analysis of Core Subsamples

Geotechnical data for the discrete samples collected within each core are presented in Appendix C-1. Summary statistics of the geotechnical parameters analyzed for the cap and dredged material units are presented in Tables 4.7-1 and 4.7-2, and discussed in the following sections.

4.7.1 Water Content

With the exception of two samples, the water content of the cap material was relatively uniform throughout all of the cores, ranging from 20 to 30% and averaging 26% ± 13.6 (Table 4.7-1). The exceptions were the sample collected at a depth of 20 cm in Core HU (HU+20) and the sample collected at a depth of 100 cm in Core HV (HV+100). Sample HU+20 had the highest water content (92%) of any of the cap samples. This sample was collected from a 15 cm band of black clay within the dark gray sand cap material. The high water content of this sample can be attributed to the clayey sediment from which the sample was collected from. Sample HV+100 also had an elevated water content of 60%. Unlike sample HU+20, this sample was collected from an interval described as sand. The results for samples HV+100 and HU+20 skew the upper range of water content values but have a minimal affect on the overall average water content. Excluding these two samples, the majority of the water content values ranged from 18 to 32%, with an average of 22 ± 2.3%.

Water content in the dredged material unit ranged from 21 to 119%, with an average value of 67 ± 23.3% (CV=34.7%; Table 4.7-2). Four samples contained water content values greater than 100% (H4-232, HT-167, HV-180, and G5-137). All of these samples were collected from sediment described as clay. The water content of the dredged material unit was more variable than that of the cap material unit. The dredged material indicated various levels of consolidation. Generally, areas of low consolidation had higher water content values, while those samples with relatively low water content values represented more consolidated sediments. Cores G3, G5, G6, H2, HS, HT and HU contained red below the dredged material and contained reduced water content values below the majority of the dredged material (in the clay). The red clay detected in these seven cores generally had a very low water content (20–30%), similar to the cap material.

The water content profiles in Appendix C-2 clearly reflect the three types of sediment found in the cores (cap material, dredged material and red clay) based on the distinct signature of each sediment type and the associated water content value. Individual water content results, per subsample location, are included in Appendix C-3.

4.7.2 Bulk Density

In general, bulk density is inversely proportional to water content. During the process of consolidation, interstitial water is forced from pore spaces, and that volume is then replaced by sediment. This results in more sediment being present within an equal sample volume, thereby

Table 4.7-1.
Summary of Physical Properties of the Cap Material
Based on Core Subsamples Collected in 2002

	CAP MATERIAL					
	Average	Standard Deviation	Coefficient of Variation (%)	Minimum	Maximum	Sample Count
Gravel (%)	0.9	0.8	-	0.0	2.9	17
Coarse Sand (%)	1.2	0.9	-	0.2	4.3	17
Medium Sand (%)	13.4	3.9	-	8.0	23.4	17
Fine Sand (%)	84.2	4.6	5.4	70.5	89.8	17
Silt (%)	-	-	-	-	-	-
Clay (%)	-	-	-	-	-	-
Passing No. 200 (%)	0.3	0.1	24.8	0.2	0.5	17
Water Content* (%)	26.4	13.6	51.3	18.0	92.0	53
Bulk Density** (g/cc)	1.8	0.1	4.4	1.5	2.0	53
USCS Symbol(s)	SP					17

*Water Content corrected for 35 pptr salinity
**Bulk Density based on wet weight
CV (%) calculated for >20%

Table 4.7-2.
Summary of Physical Properties of the Dredged Material
Based on Core Subsamples Collected in 2002

	DREDGED MATERIAL					
	Average	Standard Deviation	Coefficient of Variation (%)	Minimum	Maximum	Sample Count
Gravel (%)	1.9	6.7	-	0.0	28.0	17
Coarse Sand (%)	0.8	1.6	-	0.0	6.6	17
Medium Sand (%)	4.3	6.5	-	0.1	19.3	17
Fine Sand (%)	13.6	19.3	-	1.7	80.7	17
Silt (%)	31.6	12.0	37.8	2.7	53.1	17
Clay (%)	47.9	16.5	34.5	4.1	63.0	17
Passing No. 200 (%)	-	-	-	-	-	-
Water Content* (%)	67.0	23.3	34.7	21.0	119.0	87
Bulk Density** (g/cc)	1.7	0.2	10.4	1.4	2.1	87
Specific Gravity -	2.6	0.1	2.4	2.5	2.8	15
Shear Strength kPa	32.8	14.4	43.7	13.0	62.1	13
USCS Symbol(s)	CH (12), CL (2), ML (1), GC (1), SP-SC (1)					17

*Water Content corrected for 35 pptr salinity
**Bulk Density based on wet weight
CV (%) calculated for >20%

increasing the material's bulk density. Within the cap material, the average bulk density was 1.8 ± 0.1 g/cc, with a range of 1.5 to 2.0 g/cc (Table 4.7-1). The bulk density for cap material has not changed since the last survey. The bulk density of the cap material during the 1997 ranged from 1.8 to 2.01 g/cc with an average of 1.9 ± 0.04 g/cc.

Within the dredged material unit, the average bulk density was 1.7 ± 0.2 g/cc, and ranged from 1.4 to 2.1 g/cc. The average bulk density of the dredged material unit has changed only slightly from 1.57 g/cc (May 1997 survey) to 1.7 g/cc (August 2002 survey; Table 4.7-2). The bulk density of the underlying dredged material in the 2002 survey appeared to be approaching that of the cap material (1.8 g/cc). Appendix C-2 indicates the consistency of bulk density values down core and Appendix C-3 contains individual subsample results.

4.7.3 Grain Size

Grain size measurements indicated a sharp distinction between the sand cap and the underlying finer grained dredged material (Tables 4.7-1 and 4.7-2). Within the cap material, fine sand was the major mode (average 84%) and showed the least variation among cores (CV=5.4%; Table 4.7-1). Medium sand (average 13%) and coarse sand (average 1.2%) fractions were also significant components of the cap. Silts and clay combined contributed to less than 1% of the cap material.

The dredged material indicated a major mode of clay (average 48%) and silt (average 32%, Table 4.7-2). Fine sand (average 14%) and medium sand (average 4%) fractions were also significant components of the dredged material. Gravel and coarse sand were present at less than 2% frequency. Variability from core to core was high for silts and clay with CV=38% and CV=35% respectively. Individual grain size results, per subsample location, are included in Appendix C-4.

4.7.4 Specific Gravity

Specific gravity measurements were only performed on the dredged material unit. Specific gravity of a soil is used in calculating the phase relationships of soils, that is, the relative volumes of solids to water and air in a given volume of soil. Specific gravity typically refers to naturally occurring mineral particles that are not readily soluble in water. The specific gravity of the dredged material unit ranged from 2.5 to 2.8, averaging 2.6±0.2 (Table 4.7-2). Specific gravity was not analyzed for sediment samples collected in the 1997 survey; however, it was analyzed during the May and December 1994 surveys. The specific gravity of the dredged material unit for these historical surveys ranged from 2.6 to 2.7, this is consistent with the 2002 values. Individual specific gravity results, per subsample location, are included in Appendix C-3.

4.7.5 Shear Strength

Shear strength measurements were only made on the dredged material unit of the cores. The high sand content of the cap material rendered shear strength analysis invalid for this unit. Therefore, Core G6 (containing all sand) was not analyzed for shear strength. Core GX was also sand, however, shear strength was tested in a small pocket of dredged material layered within the sand. Shear strength was not measured in the red clay. The shear strength of the dredged material unit was highly variable (CV=43%), ranging from 13 to 62 kPa and averaging 33±14 kPa (Table 4.7-2). The highest shear strength was in Core H3 in the clayey dredged material immediately below the cap material, while the lowest shear strength value was noted in Core G6 in an area below the cap described as mottled black and red clay. Individual shear strength values for the cores are included in Appendix C-5.

4.7.6 USCS Classification

Based on the Unified Soil Classification System (USCS), the classification for the sand cap (Table 4.7-1) was uniformly SP (poorly sorted sand). Classification of the dredged material indicated variability within this unit. The black silty clay (12 samples) was primarily classified as CH or a fat clay with sand. Two samples consisted of sandy lean clay (CL). Only one sample of each of the following classifications was noted: SP-SC or poorly graded sand with clay, GC or clayey gravel, and ML or black silt.

4.8 Chemical Analysis of Sediment Core Subsamples

The following sections present the sediment chemistry results for the summer 2002 coring survey over the 1993 Dioxin Mound. As previously described, the sand cap material in six cores was sampled for TOC, dioxin, and furan analyses at 10 and 30 cm above the sand cap/dredged material interface. Likewise, the underlying dredged material in the same six cores was sampled at 10 and 30 cm below the interface.

4.8.1 Total Organic Carbon (TOC)

TOC concentrations in the core samples ranged from <0.1 (less than the detection limit) to 1.8% (Table 4.8-1). The cap material had the lowest TOC concentrations. Over half of the samples collected from the cap material contained TOC values below the detection limit. Where detected, TOC in the cap material ranged from 0.12 to 0.43%, with an overall average value of 0.23% ± 0.12 (Table 4.8-1). The TOC values from the May 1997 survey indicated a similar range of 0.046 to 0.48 % for the cap material.

The dredged material unit contained higher TOC values ranging from 1.5 to 1.8%, with an overall average value of 1.6% ± 0.12 (Table 4.8-1). The TOC results from the May 1997 survey indicated a wider range of values; 0.74 to 4.25 % and an average of 2.6 % for the dredged material.

Overall, the 2002 TOC values from the cap material were comparable to samples collected in the May 1997 survey of the 1993 Dioxin Mound. The TOC values detected in the dredged material during the 2002 survey were slightly less than those detected in the 1997 survey. None of the samples collected during the 2002 survey contained values as high as those detected in the May 1997 survey.

Table 4.8-1.
Total Organic Carbon Concentrations in
Core Subsamples for the 2002 Monitoring Survey

Core	Sample ID [1]	Results (mg/kg)	TOC (%, dry wt.)	Material Type
G2	G2+200	1200	0.12	sand cap
	G2+220	<1000	<0.1 [2]	sand cap
	G2-240	15000	1.5	dredged material
	G2-260	15000	1.5	dredged material
G3	G3+228	<1000	<0.1	sand cap
	G3+248	4300	0.43	sand cap
	G3-268	15000	1.5	dredged material
	G3-278	15000	1.5	dredged material
H3	H3+132	2300	0.23	sand cap
	H3+152	<1000	<0.1	sand cap
	H3-172	18000	1.8	dredged material
	H3-192	16000	1.6 [3]	dredged material
H4	H4+162	2200	0.22	sand cap
	H4+182	<1000	<0.1	sand cap
	H4-202	16000	1.6	dredged material
	H4-222	18000	1.8	dredged material
HT	HT+107	1600	0.16	sand cap
	HT+87	<1000	<0.1	sand cap
	HT-127	17000	1.7	dredged material
	HT-147	17000	1.7	dredged material
HV	HV+100	<1000	<0.1	sand cap
	HV+120	<1000	<0.1	sand cap
	HV-140	15000	1.5	dredged material
	HV-160	17000	1.7	dredged material

[1] indicate samples collected above and (-) below the cap/dredged material interface at 6 cm sample intervals.
[2] <0.1 is less than the detectable limit.
[3] Value represents average concentration based on triplicate analysis.

4.8.2 Dioxin and Furan Concentrations

Sediment concentrations of all measured PCDDs/PCDFs, including congener data, are presented on a dry weight basis for the six cores in Appendix C-6. Samples were collected from both the sandy cap material as well as the underlying dredged material. Results are summarized based on these two classifications in Tables 4.8-2 and 4.8-3.

All 12 of the samples collected from the cap material contained dioxin concentrations below the Level of Detection (LOD). Averages were calculated for samples with no associated value (below the detection limit) by using a value of one-half of the LOD. Using one-half of the detection limit, the dioxin concentrations in the cap material ranged from 0.095 to 0.3 pptr, with an average value of 0.13 pptr ± 0.06 (Table 4.8-2).

Furan values for these same 12 cap samples were also below the LOD or the calibration range. However, one exception was sample HT+107 in which there was interference and the resulting value was an estimated maximum possible concentration of 0.2 pptr. Overall, the furan concentration values in the cap material ranged from 0.095 to 0.21 pptr with an average of 0.12 pptr ± 0.04 (Table 4.8-3). Overall, the lack of any detectable concentrations of furan or dioxin above the required detection limit of 1.0 pptr provides evidence for negligible vertical transport of these compounds into the cap material.

Twelve samples were collected from the dredged material; all reported dioxin values were based on signal-to-noise measurements. Recorded values ranged from 1 to 100 pptr with an average value of 40 ± 34 pptr (Table 4.8-2). Four samples had a concentration greater than 39 pptr: HT-127, HT-147, H4-202 and H3-192. The highest concentration was noted in H4-202 (100 pptr), however, it should be noted that a sampled collected 20 cm deeper in the core (H4-222) indicated a significant decrease in dioxin concentration (10 pptr), while 20 cm up in the core (H4+182) was a 'non-detect' for dioxin. The H4-202 sample appears to be a unique pocket of elevated dioxin, well isolated by the cap. Sample H3-192 contained a slightly elevated concentration (70 pptr) compared to other samples collected during this survey. Core HT contained higher concentrations at 127 cm than at 147 cm (89 and 73 pptr). Both of these concentrations are higher then the majority of the samples collected during the survey. The samples collected from the cap material for all of these cores (including Core HT) did not indicate any elevation in dioxin concentrations. The higher values detected in the dredged material were expected and are not unusually high for this material based on past survey results. The detected values of furan in the dredged material ranged from 0.38 to 32 pptr with an average of 9.6 ± 10 pptr (Table 4.8-3). Only three samples contained concentrations of furan over 10 pptr: HT-127, HT-147 and H4-202 (32, 23 and 22 pptr). The samples collected from the cap material of these same cores indicated non-detectable concentrations of furan and the higher concentrations seen in the dredged material do not appear to have influenced the cap material. The average concentration of furan (9.6 pptr) is lower than that seen in previous surveys of this mound. The 1997 survey of the Dioxin Mound indicated average furan values of 14 pptr while the 1995 survey had concentrations of approximately 13 pptr.

Table 4.8-2.
Summary of Dioxin and Furan Concentrations in the
Cap Material for the 2002 Survey of the 1993 Dioxin Mound

Compound Name	Average (pptr)	Stdev.	Minimum	Maximum	Number of Samples
2,3,7,8-TCDF (Furan)	0.12	0.04	0.095	0.21	12
2,3,7,8-TCDD (Dioxin)	0.13	0.06	0.095	0.3	12
1,2,3,7,8-PeCDF	2.45	6.79	0.48	24	12
2,3,4,7,8-PeCDF	0.87	1.30	0.48	5	12
1,2,3,7,8-PeCDD	0.62	0.44	0.48	2	12
1,2,3,4,7,8-HxCDF	1.95	5.05	0.48	18	12
1,2,3,6,7,8-HxCDF	0.71	0.77	0.48	3.15	12
2,3,4,6,7,8-HxCDF	0.63	0.48	0.48	2.15	12
1,2,3,7,8,9-HxCDF	0.53	0.15	0.48	1	12
1,2,3,4,7,8-HxCDD	0.57	0.29	0.48	1.5	12
1,2,3,6,7,8-HxCDD	0.99	1.74	0.48	6.5	12
1,2,3,7,8,9-HxCDD	0.72	0.80	0.48	3.25	12
1,2,3,4,6,7,8-HpCDF	0.80	0.50	0.48	1.9	12
1,2,3,4,7,8,9-HpCDF	0.71	0.77	0.48	3.15	12
1,2,3,4,6,7,8-HpCDD	2.22	1.90	0.49	7.1	12
OCDF	2.28	2.42	0.95	7.5	12
OCDD	23.70	17.00	6.4	66	12
TEC	**0.08**	**0.11**	**0.0064**	**0.38**	**12**

Table 4.8-3.
Summary of Dioxin and Furan Concentrations in the
Dredged Material for the 2002 Survey of the 1993 Dioxin Mound

Compound Name	Average (pptr)	Stdev.	Minimum	Maximum	Number of Samples
2,3,7,8-TCDF (Furan)	9.66	10.16	0.38	32	12
2,3,7,8-TCDD (Dioxin)	40.68	34.03	1	100	12
1,2,3,7,8-PeCDF	43.39	61.35	2.5	190	12
2,3,4,7,8-PeCDF	12.07	11.73	0.465	39	12
1,2,3,7,8-PeCDD	4.38	3.46	0.465	11	12
1,2,3,4,7,8-HxCDF	39.09	54.61	0.47	200	12
1,2,3,6,7,8-HxCDF	10.40	11.80	0.465	42	12
2,3,4,6,7,8-HxCDF	6.84	6.03	0.465	20	12
1,2,3,7,8,9-HxCDF	3.17	2.92	0.465	10	12
1,2,3,4,7,8-HxCDD	3.47	2.58	0.465	8.7	12
1,2,3,6,7,8-HxCDD	16.74	16.06	0.465	52	12
1,2,3,7,8,9-HxCDD	7.04	5.61	0.465	16	12
1,2,3,4,6,7,8-HpCDF	175.57	229.15	4.4	820	12
1,2,3,4,7,8,9-HpCDF	7.68	8.23	0.465	31	12
1,2,3,4,6,7,8-HpCDD	277.25	324.49	11	1200	12
OCDF	312.05	409.76	5.9	1500	12
OCDD	2545.00	2696.75	220	9900	12
TEC	**62.28**	**57.73**	**1.6**	**180**	**12**

4.8.3 Toxic Equivalent Concentrations

The concentrations of congeners in the sediments have been expressed in terms of 2,3,7,8-TCDD Toxic Equivalents Concentrations (TECs; Safe 1990) for each sediment sample (Appendix C-6). In general, TEC values mimic those of dioxin. TECs are summarized for both the cap and dredged material units in Tables 4.8-2 and 4.8-3. The cap material had a low average TEC (0.08 ± 0.11 pptr), while the silty clay dredged material had a high average TEC, along with high variability (62± 57 pptr). The average TEC in the 1997 survey was 52± 52 pptr (SAIC 1998). Thus, the high variability and the associated TEC values detected in this survey were anticipated.

5.0 DISCUSSION

The summer 2002 monitoring of the 1993 Dioxin Capping Project utilized a suite of survey techniques, including precision bathymetry, side-scan sonar, sub-bottom profiling, REMOTS sediment-profile imaging, benthic grab sampling and coring. These same techniques have been utilized at various times over the past decade to monitor seafloor conditions prior to, during, and following the construction of the capped mound. In particular, after the capping operation was completed in February 1994, postcap monitoring surveys have been conducted at regular intervals over the ensuing years to evaluate cap stability (Figure 1.1-3).

The summer 2002 survey therefore represents the latest in a succession of postcap monitoring events designed to address the following three questions:

1) Has the cap remained stable following its original construction in February 1994?
2) Has the cap remained effective at isolating the dioxin and furan known to be present at low levels in the underlying dredged material?
3) Has the surface of the cap become recolonized by benthic organisms in a manner consistent with expectations?

The following discussion is organized around each of these three questions.

5.1 Long-Term Cap Stability

Following the completion of the capping operation in February 1994, precision bathymetric surveys were conducted over the 1993 Dioxin Capping Project Mound in March 1994, December 1994, January 1995, July 1995, and October 1996 as part of the postcap monitoring program (Figure 1.1-3). This has allowed a series of depth difference maps to be prepared, whereby the results of one bathymetric survey are compared to the results of the preceding survey to determine whether or not there were any significant changes in mound topography in the interim time period. If depths over the mound were found to be increasing over time, it would be taken as an indication of sand cap erosion or mound consolidation. The past survey results are summarized in Figure 5.1-1 (SAIC 1998). This figure shows that as of the last bathymetric survey of October 1996, there had been no significant changes in depth detected over the capped mound since the completion of the capping operation in February 1994.

To continue the sequence depicted in Figure 5.1-1, the results of the summer 2002 bathymetric survey were compared to those of the previous bathymetric survey of October 1996. The initial "depth difference" contour plot shows that the most significant depth change occurred in the area where the 1993 Dioxin Capping Project overlaps with the 1997 Category II Capping Project (Figure 4.1-2). In this area, depths were generally 2 m or 6.7 feet shallower in August 2002 compared to October 1996, reflecting the addition of capping sand during the latter half of 1997 and early 1998 over the 1997 Category II Project mound (Figure 4.1-2).

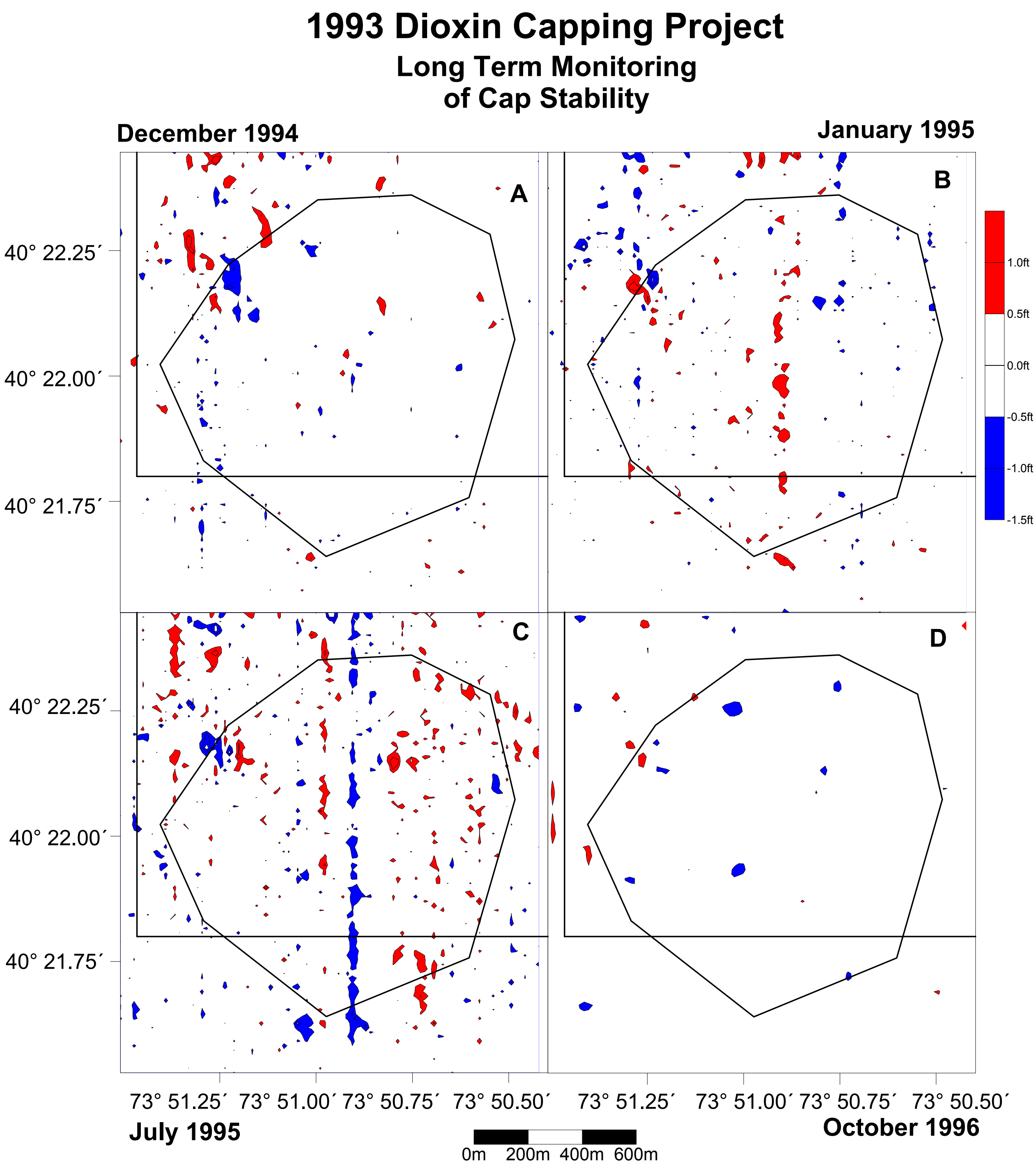


Figure 5.1-1. A series of two-dimensional contour plots showing depth differences between sequential postcap bathymetric surveys conducted over the period March 1994 to October 1996

Excluding the area of overlap between the two capping project mounds, the preliminary depth difference map suggested that depths on average were 1.3 feet shallower in 2002 over most of the 1993 Capping Project Mound compared to the previous October 1996 survey (Figure 4.1-3). One possible explanation is that the sand deposited over the 1997 Category II Capping Project mound had spread to the southwest and added to the 1993 Dioxin Mound. However, the uniformity of the apparent depth change over the entire surface of the 1993 Dioxin Mound suggests that it is more likely due to a consistent off-set in one or both of the datasets. The "corrected" depth difference map (Figure 4.1-4) shows only random positive and negative depth differences that are largely artifacts of the depth differencing procedure, consistent with the results of past surveys (Figure 5.1-1). The overall lack of significant depth difference in Figure 4.1-4 provides one line of evidence that the thickness and overall morphology of the sand cap has remained stable between the October 1996 and August 2002 surveys. This continues the pattern depicted in Figure 5.1-1 of no significant change in sand cap thickness detected through sequential bathymetric depth differencing following the completion of the cap in February 1994.

Sub-bottom profiling is a second acoustic sampling technique used in the past and during the August 2002 survey to provide insights on cap thickness and long-term stability. The 2002 sub-bottom survey results indicated an average cap thickness of 5 to 7 feet (1.5 to 2.2 m), with the greatest cap thickness in the northeast portion of the 1993 Dioxin Mound, reflecting the additional sand placed there during the 1997 Category II Project capping project (Figure 4.2-2). Two other areas along the western and southern edges of the 1993 Dioxin Mound had an apparent cap thickness of up to 9 ft (2.7 m). Overall, these 2002 survey results were consistent with the previous sub-bottom profiling results of January 1994, with the 2002 results indicating slightly greater cap thickness (by 1 or 2 feet). Some of this relatively small between-survey variability was attributed to an actual increase in cap thickness associated with the additional sand placed in 1997, and some was attributed to variability in the process of tracking and digitizing the sub-bottom reflectors. Regardless, the 2002 sub-bottom survey results support the conclusion that the sand cap has remained as a stable feature over the surface of the 1993 Dioxin Capping Project Mound.

The results of the 2002 vibracoring survey provide a third method of evaluating cap thickness and long-term stability. This method provides both an independent evaluation of cap thickness and a way to "ground truth" or verify the sub-bottom profiling and bathymetric depth differencing results. The 2002 cores showed an overall average cap thickness of approximately 150 cm (1.5 m or 4.9 ft). The previous 1997 coring survey indicated an overall average cap thickness of approximately 133 cm (1.3 m or 4.3 ft). The apparent increase of 20 cm (0.2 m or 0.5 ft) is attributed to the additional sand placed in the northeast corner of the 1993 Dioxin Mound during construction of 1997 Category II Capping Project cap. The two cores (G2 and G3) collected in this area of overlap showed significant increases in cap thickness of 116 cm (3.8 ft) and 143 cm (4.7 ft), respectively, between the May 1997 and August 2002 coring surveys. Without the increase in cap thickness noted in these two cores, the average cap thickness calculated for the 2002 survey was 4.3 ft (1.3 m), identical to the average found in the previous May 1997 survey.

Two 2002 survey cores (GX and G7) collected in the southwestern corner of the 1993 Dioxin Mound did not penetrate through the cap material and collected 246 cm (2.5 m or 8 ft) and 276 cm (2.8 m or 9 ft) of cap material, respectively. Without a distinct cap/dredged material interface visible in the cores, a determination of the actual cap thickness could not be made at these two stations. The measured cap thickness at some stations was not appreciably different between the May 1997 and August 2002 surveys, while at other stations differences of as high as 1.9 m were observed (Table 4.6-1). These results are attributed to small-scale spatial variability in the thickness of the cap over the 1993 Dioxin Capping Project Mound, as reflected to some degree in the sub-bottom profiling results as well as in the results of previous coring surveys.

A comparison of the coring and sub-bottom profiling results is presented in Table 5.1-1. This table shows the cap thickness (in feet) measured in each core compared to the cap thickness determined at the nearest sub-bottom profiling point (i.e., a point from the actual survey trackline as opposed to the less-accurate gridded data from the contour map). The overall average cap thickness of 5.5 feet (1.7 m) measured from the cores is in good agreement with the sub-bottom profiling average of 5.8 feet (1.8 m; Table 5.1-1). Although there were several stations where sub-bottom profiling either over-estimated or under-estimated the cap thickness by several feet, these results are attributed both to the actual spatial variability in cap thickness across the mound and the lower resolution (estimated to be on the order of ±1 to 3 feet) of the acoustic sub-bottom profiling method. Both sets of results, however, support the conclusion that a uniform sand cap having an average thickness of at least 1.5 m has been maintained across the surface of the 1993 Dioxin Capping Project Mound.

Finally, the REMOTS survey results provide another independent means of evaluating long-term sand cap stability. In the August 2002 survey, the spatial distribution of clean, rippled fine sand comprising the cap (Figure 4.4-1) did not differ from that found in several previous REMOTS surveys of the 1993 Dioxin Capping Project Mound. Specifically, the cap sand was consistently observed in the REMOTS images from the “Area A” stations located within the footprint of the sand cap as delimited in previous surveys. Consistent with past survey results, there were a few REMOTS stations in Area A (e.g., stations A-22 and A-18) where a layer of black, fine-grained sediment was observed underneath a surface layer of clean cap sand. The black sediment is assumed to represent a small, shallow patch of dredged material, possibly from nearby disposal operations or associated with the original placement of the capping sand. Alternately, the black sediment may represent areas where the cap sand simply has become reduced (i.e., anoxic) at depth. Based on the coring and sub-bottom profiling results showing average cap thickness of greater than 1.5 m across the entire 1993 Dioxin Mound, it is assumed that additional sand cap material underlies these shallow “puddles” of dredged material visible in the REMOTS images at the cap surface. In any future coring surveys of the 1993 Dioxin Capping Project Mound, it is recommended that cores be obtained at Stations A-22 and A-18 to verify the overall cap thickness at these locations.

Table 5.1-1.
Cap Thickness Comparison between the 2002 Cores and Sub-bottom Data Points

Core	2002 Cap Thickness (ft)	Distance of Closest Sub-bottom Data Point to Core (ft)	Cap Thickness at Nearest Sub-bottom Data Point (ft)	Difference Between Core and Sub-bottom Cap Thickness Measurements (ft)
G2	7.5	75	9.8	2.3
G3	8.5	180	8.6	0.1
G4	4.7	25	4.1	-0.6
G5	3.8	140	7.3	3.5
G6	1.9	50	3.4	1.5
G7	>8.1	150	4.4	<-3.7
GX	>9.1	230	5.2	<-3.9
H2	6.1	185	4.9	-1.2
H3	5.3	125	6.5	1.2
H4	6.2	185	5.7	-0.5
HU	1.6	220	6.3	4.7
HV	4.3	130	4.1	-0.2
HT	3.8	165	5.3	1.5
HS	5.3	10	5.3	0.0
Average	**5.5**	**133.6**	**5.8**	**0.3**

5.2 Long-Term Effectiveness of Cap in Isolating Contaminants

All twelve of the cap material samples, collected in the six cores at intervals of 10 cm and 30 cm above the cap/dredged material interface, contained negligible levels of both dioxin and furan. Specifically, dioxin and furan concentrations in all of these samples were less than the analytical Level of Detection (LOD) of 1 pptr. Detectable levels of both dioxin and furan were found in the underlying dredged material in the cores, at levels ranging from 1 to 100 pptr. Overall, these results suggest that there has been no vertical migration of dioxin and furan from the underlying dredged material into the overlying cap material layer, as these contaminants were not detected in any of the cap material samples.

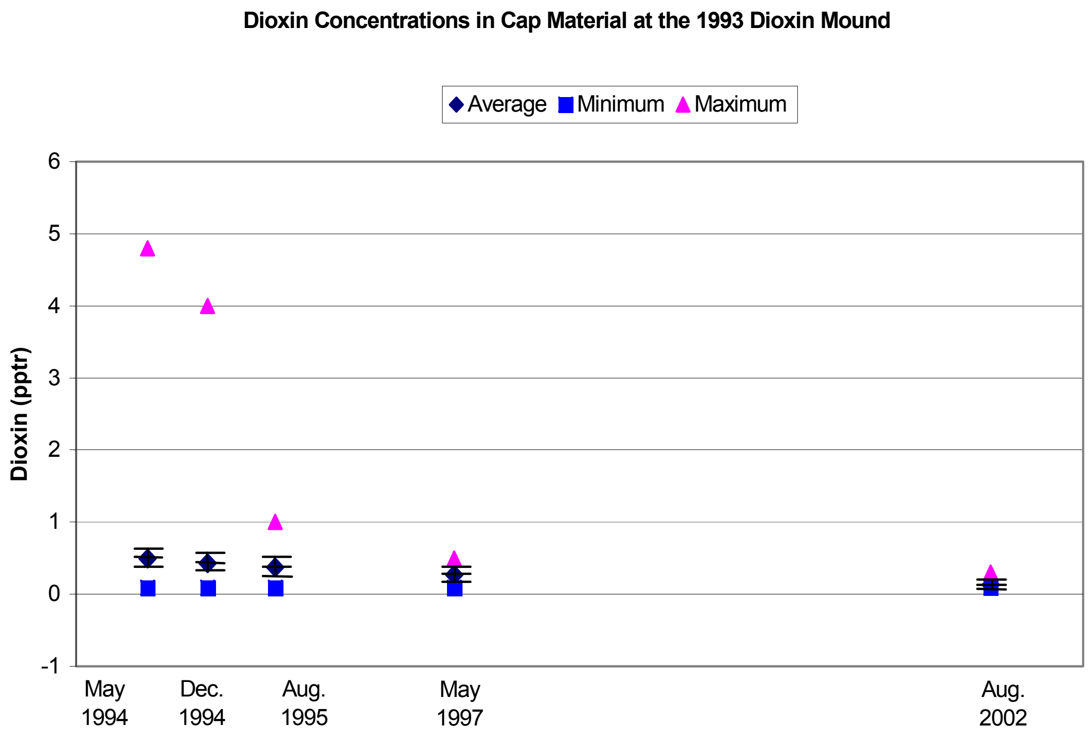
The dioxin and furan results from the August 2002 survey are consistent with those of the four previous postcap coring surveys (May 1994, December 1994, August 1995, and May 1997) over the 1993 Dioxin Capping Project Mound (Figures 5.2-1 and 5.2-2). In every survey, the measured concentrations of dioxin and furan in the cap material have been negligible, with the overall averages consistently below the required detection limit of 1 pptr (Figure 5.2-1). In general, the critical period for potential contamination of cap sediments is during the early stages of a capping project, when consolidation may cause pore water to move up (advect) from the contaminated dredged material into the overlying cap layers. However, the results of the five postcap coring surveys demonstrate that this process, if it was occurring, has not resulted in any measurable increase in contaminants in the cap over the 1993 Dioxin Capping Project Mound (Figure 5.2-1). The 2002 results support the conclusion that the cap continues to remain effective in isolating the dioxin and furan in the underlying dredged material.

The average dioxin and furan concentrations measured in the underlying, fine-grained dredged material in each of the five postcap coring surveys have consistently been elevated relative to the overlying cap material (Figure 5.2-2). Based on the standard deviations and minimum/maximum values shown in Figure 5.2-2, the measured dioxin and furan concentrations in the dredged material have been variable, both within and among surveys. These elevated concentrations are not unexpected, given the pre-dredging characterization of these sediments as Category II dredged material requiring capping.

5.3 Benthic Recolonization Status of the Capped Mound

In past REMOTS surveys over the 1993 Dioxin Mound, it was found that the rippled fine sand comprising the cap had been recolonized by a benthic community consisting of tube-dwelling, small-bodied polychaetes inhabiting the sediment surface (i.e., pioneering Stage I organisms). A similar Stage I benthic community also has been found in the past to be dominant at the South Reference Area. The 2002 REMOTS survey results are in good agreement with these previous results; Stage I was the dominant successional stage at both the mound and reference area stations.

The consistency of these results over many years of monitoring support the conclusion that infaunal succession beyond Stage I is not likely to occur on the sand cap or in the reference area. The ripples observed in both areas suggest that the sand experiences periodic bedload transport, most likely from elevated bottom currents or wave action during the passage of large storms.



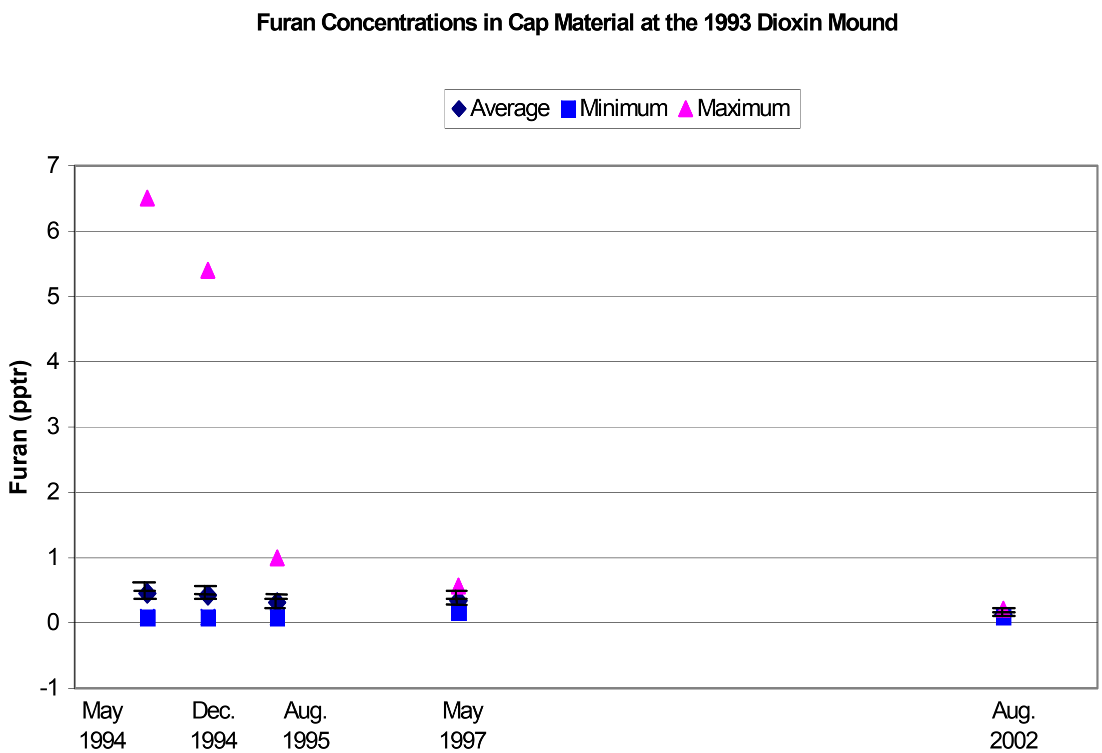
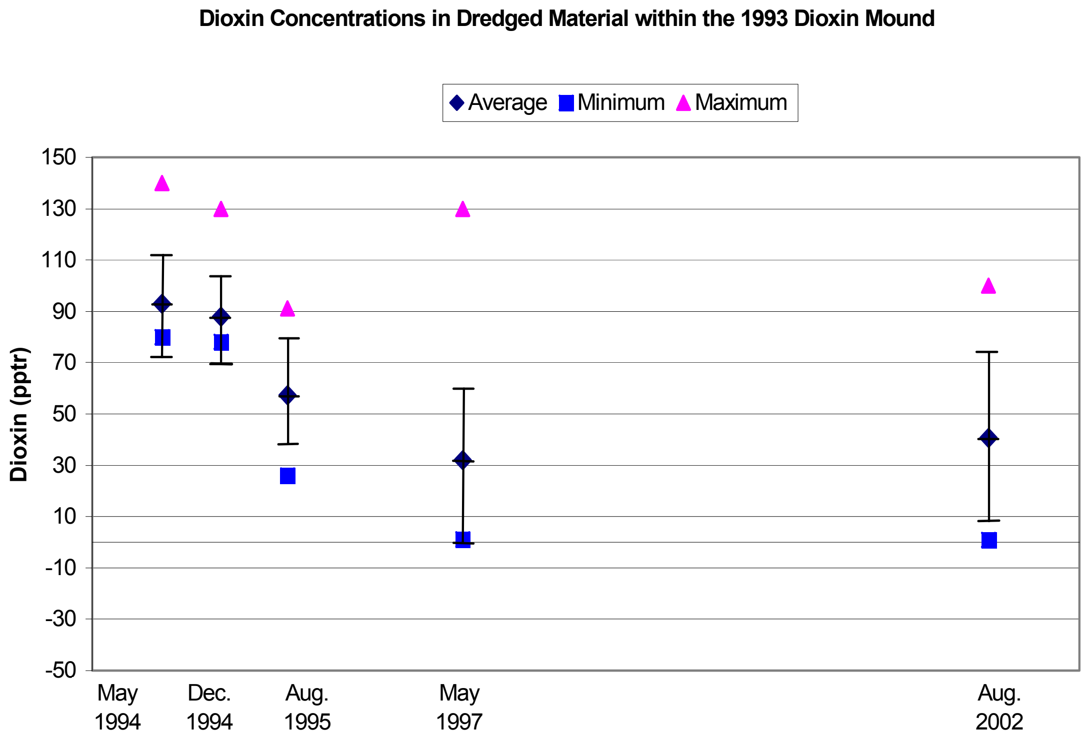


Figure 5.2-1. Dioxin and furan concentrations measured in the cap material at the 1993 Dioxin Mound in coring surveys conducted over the period 1994 to 2002



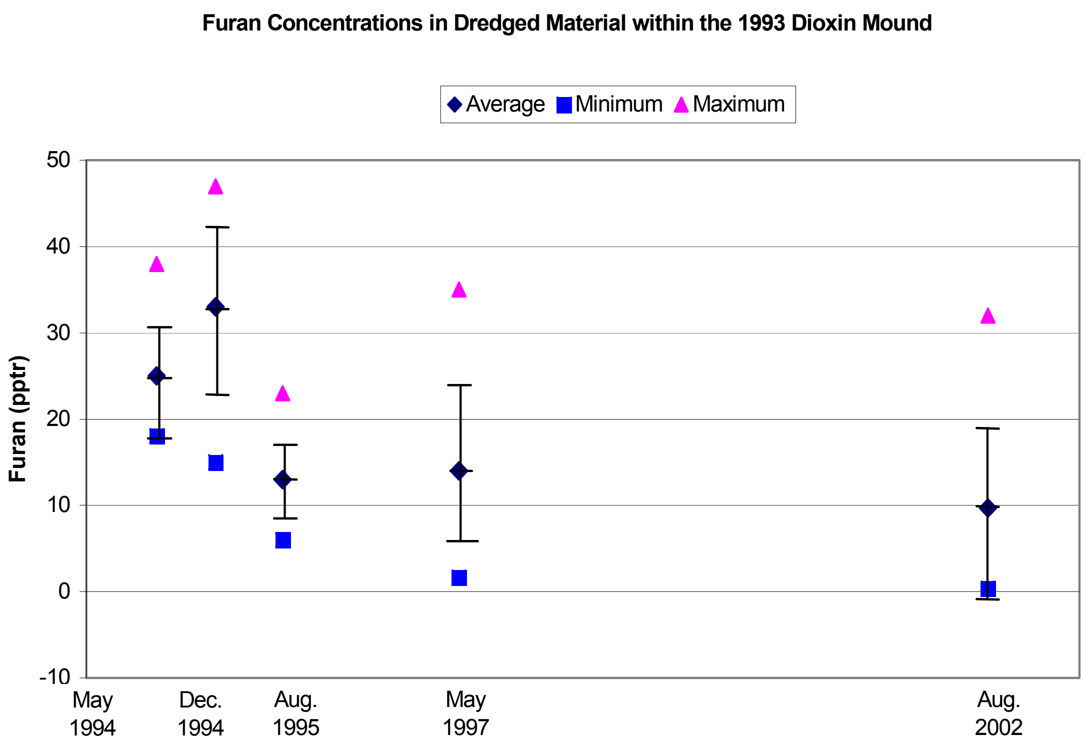


Figure 5.2-2. Dioxin and furan concentrations measured in the dredged material at the 1993 Dioxin Mound in coring surveys conducted over the period 1994 to 2002

The physical instability of the sand surface favors the long-term dominance of surface-dwelling, opportunistic organisms. In addition, larger-bodied, Stage III deposit-feeders require soft, organic-rich sediments; Stage III communities have difficulty becoming established on clean, rippled sand bottoms. At many of the stations surrounding the 1993 Dioxin Mound, where fine-grained, organic-rich dredged material from past disposal activities is present, the mixed community of both surface-dwellers (Stage I) and sub-surface deposit-feeders (Stage III) that has been found in the past was also observed in the 2002 survey.

At several of the 2002 stations located over the 1993 Dioxin Mound sand cap, the REMOTS images revealed stick-dwelling or stalked amphipods of the Family Podoceridae at the sediment surface (e.g., Figure 4.4-3). There is a strong probability that these amphipods are *Dulichia porrecta*, as this Podocerid species was found among the 15 most abundant taxa in the benthic grab samples collected at selected REMOTS stations over the 1993 Dioxin Mound sand cap (Table 4.5-2). The amphipod stalks appear to be delicate structures that are probably not able to withstand elevated bottom currents or sand movement. Their presence on the 1993 Dioxin Mound during the summer 2002 REMOTS survey suggests that the mound surface had probably not experienced significant sand movement or elevated bottom currents for at least several weeks or months preceding the survey. Given the likelihood that the delicate stalks would be removed during higher-energy storm events, the stick-dwelling amphipod *Dulichia porrecta* may only be an ephemeral member of the Stage I/II community inhabiting the surface of the sand cap.

The taxonomic data from the benthic grabs provides a means of "ground-truthing" the REMOTS image interpretation. The numerically dominant taxa at both the capped mound and South Reference Area stations included several Stage I polychaetes and/or Stage II amphipods. The Stage II bivalve *Nucula proxima* likewise was found in very high numbers at stations over the capped mound. These results agree with the REMOTS data showing a dominance of Stage I and some Stage II over the surface of the capped mound (Figure 4.4-17). The taxonomic data also indicated that a few Stage III polychaetes (e.g., *Nepthys picta, Aricidea catherinae*) were present over the capped mound and South Reference Area, but the density of these organisms apparently was too low for them to be reliably detected in the REMOTS images. In general, many of the same taxa that were most abundant in the 2002 survey of the 1993 Dioxin Mound and South Reference Area have historically been found among the dominants in other studies of benthic assemblages in the New York Bight (Vittor and Associates 1996; Carracciolo and Steimle 1983; Chang et al. 1992).

Several of the numerically dominant taxa at the 1993 Dioxin Mound stations were also among the dominants at the South Reference Area stations, but their relative abundances differed significantly. Due to the disproportionately high numbers of the near-surface-dwelling bivalve *Nucula proxima*, the average organism abundance at the 1993 Dioxin Mound stations was much higher than at the reference area, while the two areas had equal average numbers of taxa (Table 4.5-4). In the New York Bight, *Nucula proxima* prefers fine silty sands with relatively high organic content (Caracciolo and Steimle 1983). The sands comprising the 1993 Dioxin Mound were found to be finer than those at the South Reference Area (Table 4.5-1), and they likely have higher organic content due to their proximity to nearby areas of the HARS where fine-grained, organic-rich dredged material is already present and/or continues to be placed through on-going remediation activities. Station B-8, which had the highest density of *N. proxima*, was actually located outside of the sand cap footprint in an area of historic, fine-grained dredged material.

Differences in grain size distribution and organic carbon content therefore most readily explain the observed differences in benthic community structure between the mound and reference area stations (Figure 4.5-2). Despite such differences, the taxonomic data clearly indicate that the 1993 Dioxin Capping Project Mound was supporting a relatively abundant and diverse benthic community at the time of the summer 2002 survey. This community was mainly comprised of surface-dwelling, Stage I and II taxa that are adapted to maintaining populations despite periodic physical disturbance. A predominantly Stage I community also was found at the South Reference Area, but due to higher relative proportions of medium sand, the taxonomic composition of this community was largely different from that at the 1993 Dioxin Mound. Reflecting the widespread presence of Stage I organisms and relatively well-developed aRPD depths, average OSI values of greater than +6 were calculated for both the capped mound and reference area stations. Such values are considered indicative of non-degraded benthic habitat quality in both areas at the time of the 2002 survey.

6.0 CONCLUSIONS

- The results of the precision bathymetric survey conducted over the 1993 Dioxin Capping Project Mound during summer 2002 were compared to the results of the previous bathymetric survey of October 1996. Where the 1993 Dioxin Capping Project Mound overlaps with the 1997 Category II Capping Project Mound, depths were found to be about 2 m shallower in 2002, due to the placement of sand in this area during the latter half of 1997 and early 1998 as part of the 1997 Category II Capping Project.

- Outside the area of overlap with the 1997 Category II Mound, there were no significant depth changes detected over the 1993 Dioxin Capping Project Mound between the October 1996 and summer 2002 bathymetric surveys. This is the same result that has been observed in previous bathymetric depth difference comparisons, suggesting no appreciable change in the distribution or thickness of the sand cap since its creation in 1994.

- The summer 2002 sub-bottom profiling results were consistent with the bathymetric depth differencing results, indicating an average sand cap thickness of 5 to 7 feet, with the greatest thickness (up to 9 feet) observed in the area of overlap between the 1993 and 1997 mounds.

- Sediment cores obtained in August 2002 revealed an average cap thickness of 1.5 m (4.9 ft) over the 1993 Dioxin Capping Project Mound. Cap thickness was variable among cores, ranging from 50 cm to greater than 276 cm. These results are consistent with previous postcap coring surveys and reflect small-scale spatial variability in cap thickness. Cap thickness measurements from the cores were generally comparable to the cap thickness estimates obtained through sub-bottom profiling.

- The spatial distribution of cap sand detected at the 2002 REMOTS sediment-profile imaging stations was similar to that observed in several previous postcap REMOTS surveys over the 1993 Dioxin Capping Project Mound. Overall, the combined results of the summer 2002 bathymetric, sub-bottom profiling, coring and REMOTS surveys support the conclusion that the sand cap has remained stable since its creation in 1994.

- At Stations A-22 and A-18 located on the cap, black sediment was observed in the REMOTS images underneath a surface layer of clean cap sand. The black sediment is assumed to represent either a small, shallow patch of dredged material or anoxic, sub-surface cap sand. In any future coring surveys of the 1993 Dioxin Capping Project Mound, it is recommended that cores be obtained at these two stations to verify overall cap thickness.

- Negligible concentrations of dioxin and furan (i.e., less than the 1 part per trillion level of detection) were measured in the cap material. Detectable levels of dioxin and furan in the underlying dredged material ranged from 1 to 100 parts per trillion. These results are consistent with those of four previous postcap coring surveys and indicate a lack of any significant vertical migration of dioxin or furan from the underlying dredged material into the overlying cap material. These results support the conclusion that the cap continues to remain effective in isolating the dioxin and furan.

- The 2002 REMOTS results indicated that the surface of the sand cap continued to be inhabited by a benthic community comprised of small, surface-dwelling opportunists (Stages I and II), similar to the community at the nearby South Reference Area. In the area of the HARS surrounding the sand cap, where fine-grained historic dredged material occurs, the benthic community consisted of a mixture of surface-dwellers (Stage I) and deeper-dwelling deposit-feeders (Stage III).

- Benthic grab samples showed that the numerically dominant taxa at both the 1993 Dioxin Mound and the South Reference Area included several Stage I polychaetes and Stage II amphipods. The Stage II bivalve *Nucula proxima* also was found in relatively high numbers at the stations over the capped mound. The benthic grab sampling results were generally consistent with the REMOTS results in showing that the 1993 Dioxin Mound and South Reference Area were both inhabited by relatively abundant and diverse benthic communities at the time of the summer 2002 surveys. Among-station differences in the composition of these communities were attributed to differences in sediment grain size and organic carbon content.

- Both the REMOTS and benthic grab sampling results indicate that the surface of the 1993 Dioxin Capping Project Mound represented a relatively healthy and productive habitat for benthic organisms at the time of the summer 2002 survey.

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Appendix A
REMOTS Image Analysis Results

Appendix A1

REMOTS Sediment-Profile Imaging Data from the 1993 Dioxin Mound Capping Project Area, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low	Comments
				Stage	Min	Max	Maj Mode	Habitat	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam		Roughness	DO	
A1	A	6/18/2002	12:26	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	4.79	7.04	2.25	5.91	0	0	0	0	0	0	>4.79	>7.04	>5.91	0	0	0	7	Physical	NO	Uniform sand cap material > pen. RPD>pen
A1	B	6/18/2002	12:26	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	5.48	7.57	2.09	6.53	0	0	0	0	0	0	>5.48	>7.57	>6.53	0	0	0	7	Physical	NO	Uniform sand cap material > pen. RPD>pen; small Stage 1 tubes
A10	B	6/19/2002	14:02	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.34	6	0.66	5.67	0	0	0	0	0	0	>5.34	>6.0	>5.67	0	0	0	7	Physical	NO	Uniformly sorted sand cap material >Pen, Oxygenated RPD > Pen, trace shell material, rippled surface in farfield
A10	C	6/18/2002	14:03	ST I	>4 phi	2 to 1 phi	3 to 2phi	SA.F	0	0	10.38	10.82	0.44	10.6	0	0	0	0	0	0	1.49	3.91	2.17	0	0	0	4	Physical	NO	Clean cap sand>pen; layer of reduced sed @ depth=fine grained relic DM?; Stg 1 tubes
A11	B	6/18/2002	12:53	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.02	6.39	3.37	4.7	0	0	0	0	0	0	>3.02	>6.39	>4.7	0	0	0	7	Physical	NO	Uniform sand cap materail>pen. Rippled surface. RPD>pen
A11	C	6/18/2002	13:28	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3	5.41	2.41	4.2	0	0	0	0	0	0	>3.0	>5.41	>4.2	0	0	0	7	Physical	NO	Uniform sand cap material>pen. Rippled surface. rpd>pe
A12	B	6/18/2002	12:46	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.95	6.61	2.66	5.28	0	0	0	0	0	0	1.56	5.05	3.10	0	0	0	6	Physical	NO	Uniform sand cap material>pen. Sand ripple
A12	C	6/18/2002	14:47	ST I to II	3 to 2 phi	2 to 1 phi	2 to 1 phi	SA.M	0	0	3.5	5.59	2.09	4.55	0	0	0	0	0	0	0.28	4.2	1.78	0	0	0	5	Physical	NO	Uniform cap sand>pen. Amphipod stalk
A13	B	6/18/2002	13:57	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.64	5.71	2.07	4.68	0	0	0	0	0	0	>3.64	>5.71	>4.68	0	0	0	7	Physical	NO	Uniform sand cap material>pen. Stg 1 tubes in farfield. RPD>pen
A13	C	6/18/2002	13:58	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.59	8.27	1.68	7.43	0	0	0	0	0	0	1.07	3.84	2.20	0	0	0	4	Physical	NO	Uniform sand cap>pen. Rippled.
A14	A	6/18/2002	13:43	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.75	4.71	0.96	4.23	0	0	0	0	0	0	>3.75	>4.71	>4.23	0	0	0	7	Physical	NO	Uniform sand cap material>pen. Trace amount of shell material. Sand waves in farfield. RPD>pen
A14	C	6/18/2002	13:44	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.48	4.96	2.48	3.72	0	0	0	0	0	0	>2.48	>4.96	>3.72	0	0	0	6	Physical	NO	Uniform sand cap material>pen. Apparent worm tube in farfield. rippled in farfield. RPD>pen
A15	A	6/18/2002	13:36	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.68	9.11	4.43	6.89	0	0	0	0	0	0	>4.68	>9.11	>6.89	0	0	0	7	Physical	NO	Uniform sand cap material>pen. Possible worm tube @ surf and in farfield. RPD>pen
A15	C	6/18/2002	13:37	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.61	6.68	2.07	5.64	0	0	0	0	0	0	>4.61	>6.68	>5.64	0	0	0	7	Physical	NO	Unifrom sand cap material>pen. Sand wave in farfield. Small worm tubes in farfield. RPD>pen
A16	B	6/18/2002	13:51	ST I	> 4 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.29	3.95	0.66	3.62	0	0	0	0	0	0	0.14	2.99	1.41	0	0	0	3	Physical	NO	Sand cap>pen. Some mud mixed with sand@depth Apparent clasts in farfield. Stg 1 tubes
A16	C	6/18/2002	13:51	ST I to II	> 4 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.02	3.3	1.28	2.66	0	0	0	0	0	0	0.07	2.77	1.21	0	0	0	4	Physical	NO	Sand cap>pen; reduced@depth Amphipod stalk and trace amount of shell hash in farfield.
A17	A	6/18/2002	14:44	ST I to II	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.98	5.34	3.36	3.66	0	0	0	0	0	0	2.06	5.12	2.91	0	0	0	6	Physical	NO	Sand cap material>pen. Stg 1 tubes Amphipod stalk in farfield left side.
A17	C	6/18/2002	14:45	ST I to II	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.57	4.84	2.27	3.7	0	0	0	0	0	0	>2.57	>4.84	>3.7	0	0	0	7	Physical	NO	Sand cap material > pen. rippled, RPD>pen, Amphipod stalk in farfield.
A18	A	6/18/2002	15:01	ST II	> 4 phi	2 to 1 phi	> 4 phi	SA.F	0	0	9.29	11.52	2.23	10.41	0	0	0	0	0	0	2.13	4.48	2.66	0	0	0	7	Physical	NO	S/M=Uniform sand cap material over fine-grained relic black dredged material. Amp tubes and worm tubes at surfac
A18	B	6/18/2002	15:02	ST I	> 4 phi	2 to 1 phi	3 to 2	SA.F	0	0	7.68	9.62	1.94	8.65	0	0	0	0	0	0	1.35	3.98	2.03	0	0	0	4	Physical	NO	Sand cap>pen; mixed w/ reduced DM@depth. Smearing artifact @ sed water interface; RPD measured behind smear.
A19	B	6/18/2002	15:10	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.52	6.46	1.94	5.49	0	0	0	0	0	0	>4.52	>6.46	>5.49	0	0	0	7	Physical	NO	Clean, homogenous cap sand>pen. RPD>pen. Surface organism present in farfield.
A19	C	6/18/2002	15:10	ST I	4 to 3 phi	2 to 1 phi	2 to 1 phi	SA.M	0	0	4.25	4.77	0.52	4.51	0	0	0	0	0	0	3.63	4.91	3.39	0	0	0	6	Physical	NO	Sand cap material > pen. Sand wave in farfield. Possible surface organsim in farfield.
A2	A	6/19/2002	11:09	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	0.57	3.54	2.97	2.06	0	0	0	0	0	0	>0.57	>3.54	>2.06	0	0	0	4	Physical	NO	Homogenous clean sand cap material > pen. RPD>pen Trace amount of shell fragments.
A2	B	6/19/2002	11:10	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.91	4.05	1.14	3.48	0	0	0	0	0	0	>2.91	>4.05	>3.48	0	0	0	6	Physical	NO	Homogenous clean sand cap material > pen. Shell material in farfield. Sand waves. fecal casts on sand surface, RPD>pen
A20	A	6/18/2002	15:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.M	0	0	3.5	5.41	1.91	4.45	0	0	0	0	0	0	>3.5	>5.41	>4.45	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Sand waves and possible surface organism in farfield. RPD>pen
A20	B	6/18/2002	15:36	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	2.57	4.96	2.39	3.76	0	0	0	0	0	0	2.63	4.77	2.82	0	0	0	5	Physical	NO	Homogenous sand cap material > pen. Sand wave. Small amount of shell material and surface organisms in farfiled.
A21	B	6/18/2002	15:43	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.57	5.04	2.47	3.8	0	0	0	0	0	0	2.28	4.98	2.93	0	0	0	5	Physical	NO	Homogenous sand cap material > pen. Amphipod stalk in farfield? Sand waves.
A21	C	6/18/2002	15:44	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.18	5.07	2.89	3.62	0	0	0	0	0	0	1.28	3.7	1.94	0	0	0	4	Physical	NO	Homogenous sand cap material > pen. Small patch of apparent black dm. Sand wave and org tubes-far
A22	A	6/18/2002	15:49	ST II on III	> 4 phi	2 to 1 phi	3 to 2 phi	UN.SS	0	0	9.21	10.02	0.81	9.61	0	0	0	0	0	0	1.92	4.62	2.64	0	0	0	9	Physical	NO	Apparent sand cap material / fine-grained black DM. Amp tubes & amps @surf, Numerous additional worm tubes @surf.
A22	B	6/18/2002	15:50	ST II	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	6.52	7.68	1.16	7.1	> 6.52	> 7.68	> 7.1	0	0	0	0.07	4.27	1.39	0	0	0	5	Biogenic	NO	Relic DM>pen, reduced@depth, thin patchy RPD. Numerous Stage I and II tubes at surface.
A23	B	6/18/2002	15:56	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.M	0	0	2.54	5.73	3.19	4.14	0	0	0	0	0	0	>2.54	>5.73	>4.14	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. Shell material and possible organism in farfield. Sand waves. RPD>pen
A23	C	6/18/2002	15:56	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.04	7.57	2.53	6.31	0	0	0	0	0	0	>5.04	>7.57	>6.31	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. Sand wave. RPD>pen
A24	A	6/18/2002	16:02	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.86	5.88	2.02	4.87	0	0	0	0	0	0	>3.86	>5.88	>4.87	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Surface organism tubes in farfield. RPD>pen
A24	B	6/18/2002	16:02	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.93	5.86	2.93	4.39	0	0	0	0	0	0	>2.93	>5.86	>4.39	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. Possible organism tube in farfield. RPD>pen
A25	B	6/18/2002	16:09	ST I to II	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.82	5.68	2.86	4.25	0	0	0	0	0	0	>2.82	>5.68	>4.25	0	0	0	8	Physical	NO	Homogenous sand cap material > pen. Amphipod stalks on surface, RPD>pen
A25	C	6/18/2002	16:09	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.12	6.18	2.06	5.15	0	0	0	0	0	0	>4.12	>6.18	>5.15	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. Trace amount of shell material. RPD>pen
A3	B	6/18/2002	12:18	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	5.27	5.8	0.53	5.53	0	0	0	0	0	0	>5.27	>5.8	>5.53	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. RPD>pen
A3	C	6/18/2002	12:19	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.64	4.79	2.15	3.72	0	0	0	0	0	0	>2.64	>4.79	>3.72	0	0	0	6	Biogenic	NO	Homogenous clean sand cap material > pen. RPD > pen. Sand dollars.
A4	D	6/24/2002	09:46	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.32	6.93	0.61	6.62	0	0	0	0	0	0	>6.32	>6.93	>6.62	0	0	0	7	Physical	NO	Homogenous clean sand cap material > pen. Sand waves. Shell in farfield. RPD>pen
A4	E	6/19/2002	09:47	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	5.61	7.14	1.53	6.38	0	0	0	0	0	0	>5.61	>7.14	>6.38	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Small tube @ surface. RPD>pen
A5	B	6/18/2002	12:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.14	3.88	2.74	2.51	0	0	0	0	0	0	>1.14	>3.88	>2.51	0	0	0	5	Physical	NO	Homegenous sand cap material > pen. Sand wave. RPD>pen
A5	C	6/18/2002	12:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.73	3.95	2.22	2.84	0	0	0	0	0	0	>1.73	>3.95	>2.84	0	0	0	5	Physical	NO	Homegenous sand cap material > pen. RPD depth > pen. Sand wave. Shell in farfield.
A6	A	6/18/2002	14:23	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.55	5.75	1.2	5.15	0	0	0	0	0	0	>4.55	>5.75	>5.15	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Sand wave in farfield. RPD>pen
A6	B	6/18/2002	14:24	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.54	3.89	0.35	3.72	0	0	0	0	0	0	>3.54	>3.89	>3.72	0	0	0	6	Physical	NO	Homogenous sand cap material > pen. Surface organisms in farfield. RPD>pen
A7	A	6/18/2002	14:06	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.3	5.5	1.2	4.9	0	0	0	0	0	0	0.5	3.84	2.25	0	0	0	4	Physical	NO	Homogenous sand cap > pen. Small parch of grey/black sand. Organism tubes in farfield.
A7	C	6/18/2002	14:08	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.14	6.39	1.25	5.76	0	0	0	0	0	0	>5.14	>6.39	>5.76	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Sand wave. RPD>pen.
A8	A	6/18/2002	14:15	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.27	4.86	1.59	4.07	0	0	0	0	0	0	0.85	2.42	1.31	0	0	0	3	Physical	NO	Homogenous sand cap material layer>pen; reduced lyr@depth=relic dm? shell fragments. Fecal casts on surface
A8	C	6/18/2002	14:16	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.73	6.04	4.31	3.88	0	0	0	0	0	0	>1.73	>6.04	>3.88	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Fine-grained black dredged material smears. Shell material in farfield. rippled. RPD>pen
A9	B	6/18/2002	14:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.M	0	0	2.41	6.07	3.66	4.24	0	0	0	0	0	0	>2.41	>6.07	>4.24	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. rippled RPD>pen
A9	C	6/18/2002	14:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.75	5.82	3.07	4.28	0	0	0	0	0	0	>2.75	>5.82	>4.28	0	0	0	7	Physical	NO	Homogenous sand cap material > pen. Snail on shell. Sand wave in farfield. RPD>pen
B1	A	6/19/2002	13:06	ST I	> 4 phi	< -1 phi	4 to 3 phi	HR	0	0	0.98	3.29	2.31	2.13	0	0	0	0	0	0	-99	-99	-99.00	0	0	0	99	Physical	NO	Encrusted cobble overlying fine sand. RPD indeterminate due to low pen & homogenous colored sediments, active surf biology.
B1	B	6/19/2002	13:06	ST I	> 4 phi	1 to 0 phi	2 to 1 phi	SA.M	3	0.57	10.96	11.73	0.77	11.34	0	0	0	0	0	0	2.35	5.69	3.34	0	0	0	6	Physical	NO	Medium ambient sand>pen. Small clasts and tubes at surface. Possible rocks in farfield.
B10	C	6/24/2002	10:53	INDET	< -1 phi	< -1 phi	< -1 phi	HR	0	0	-0.04	0.04	0.08	.	0	0	0	0	0	0	-99	-99	-99.00	0	0	0	99	Physical	NO	No prism penetration. Apeears to be cobble/rock bottom. Possibly encrusted.
B10	D	6/24/2002	09:56	INDET	> 4 phi	4 to 3 phi	4 to 3 phi	UN.SS	0	0	3.2	4.71	1.51	3.95	0	0	0	0	0	0	-99	-99	-99.00	0	0	0	99	Physical	NO	Very fine silty mud. Ambient sed? Low pen. RPD indistinguishable. Shells on surface.
B11	A	6/19/2002	10:46	ST I on III	> 4 phi	3 to 2 phi	> 4 phi	UN.SI	1	0.57	9.8	10.79	0.99	10.3	> 9.8	> 10.79	> 10.3	0	0	0	0.57	2.56	1.20	0	0	0	7	Physical	NO	Sand over historic DM; historic DM>P; sand=cap? Voids, worm @z, sm clast, shell material on surf-far, possible surface org-far.
B11	C	6/24/2002	10:47	ST I	> 4 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	12.07	14.18	2.11	13.12	12.07	14.18	13.12	0	0	0	0.07	6.26	3.52	0	0	0	6	Physical	NO	Homogenous sand cap material over fine-grained black relic dredged material.
B12	A	6/19/2002	10:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.45	4.32	0.87	3.89	0	0	0	0	0	0	3.06	4.05	2.83	0	0	0	5	Physical	NO	Homogenous sand cap material > pen. Amphipod stalks in farfield. Trace amount of shell material.
B12	C	6/19/2002	10:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.25	6.61	2.36	5.43	0	0	0	0	0	0	3.27	5.97	3.61	0	0	0	6	Physical	NO	Homogenous sand cap material > pen. RPD>pen, Surface Hydroids? in farfield. Trace amount of shell material.
B13	A	6/19/2002	10:40	ST I to II	> 4 phi	3 to 2 phi	4 to 3 phi	UN.SS	0	0	5.89	6.62	0.73	6.26	> 5.89	> 6.62	> 6.26	0	0	0	1.49	3.77	2.24	0	0	0	5	Physical	NO	Sandy relic DM >pen, Amphipod stalks and dense poly tubes. Trace amount of shell material.
B13	B	6/19/2002	10:40	ST I to II	> 4 phi	3 to 2 phi	4 to 3 phi	UN.SS	0	0	6.46	7.11	0.65	6.78	> 6.46	> 7.11	> 6.78	0	0	0	1.85	4.55	2.68	0	0	0	6	Physical	NO	Sandy relic DM>pen. Amphipod stalk and tubes
B2	A	6/19/2002	12:07	ST I	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	10.59	11.2	0.61	10.9	> 10.59	> 11.2	> 10.9	0	0	0	0.14	5.62	2.88	0	0	0	5	Physical	NO	Relic dm>p; well-developed RPD, surface tubes
B2	C	6/19/2002	12:09	ST I	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	9.12	9.62	0.5	9.37	> 9.12	> 9.62	> 9.37	0	0	0	1.56	5.26	3.37	0	0	0	6	Physical	NO	Relic dm>p; well-developed RPD; biogenic surface reworking
B3	A	6/19/2002	12:41	ST I	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	3.3	4.05	0.75	3.68	0	0	0	0	0	0	>3.3	>4.05	>3.68	0	0	0	6	Physical	NO	ambient muddy sand>p; RPD>p; Tubes at surface.
B3	C	6/19/2002	12:59	ST I	> 4 phi	2 to 1 phi	> 4 phi	UN.SI	0	0	16.68	17.62	0.94	17.15	0	0	0	0	0	0	0.07	4.98	2.72	0	0	0	5	Physical	NO	Very fine gray mud over brown coarser-grained sand, relic DM? Floccuent layer @surf, sm tubes@ surf, sm pieces of shell hash @z.
B4	A	6/19/2002	13:14	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.71	4.34	1.63	3.53	0	0	0	0	0	0	>2.71	>4.34	>3.53	0	0	0	6	Physical	NO	Sand cap material > pen. rippled; RPD>pen
B4	C	6/19/2002	13:15	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.82	6.04	2.22	4.93	0	0	0	0	0	0	>3.82	>6.04	>4.93	0	0	0	7	Physical	NO	Sand cap material > pen. Small tubes at surface. Rippled; RPD>pen
B5	A	6/19/2002	13:31	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.68	5.2	0.52	4.94	0	0	0	0	0	0	>4.68	>5.2	>4.94	0	0	0	7	Physical	NO	Sand cap material > pen. RPD>pen
B5	C	6/19/2002	13:33	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.66	3.57	1.91	2.62	0	0	0	0	0	0	>1.66	>3.57	>2.62	0	0	0	5	Physical	NO	Sand cap material > pen. Rippled. Small shell fragments. RPD>pen
B6	B	6/19/2002	12:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.09	3.79	1.7	2.94	0	0	0	0	0	0	>2.09	>3.79	>2.94	0	0	0	5	Physical	NO	Fine-grained ambient sand > pen. Burrow or sediment fracture from penetration? Shells and shell fragments at surface. RPD>pen
B6	C	6/19/2002	12:35	ST I	> 4 phi	3 to 2 phi	> 4 phi	UN.SS	0	0	6.59	10.23	3.64	8.41	> 6.59	> 10.23	> 8.41	0	0	0	0.07	3.27	1.42	0	0	0	3	Biogenic	NO	Relic sandy DM>pen. Dissected burrow Brick frags or pebbles farfield
B7	A	6/19/2002	13:21	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.18	5.68	1.5	4.93	0	0	0	0	0	0	>4.18	>5.68	>4.93	0	0	0	7	Physical	NO	Clean homogenous and cap material > pen. Rippled. RPD>pen
B7	C	6/19/2002	13:22	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	1.66	5.27	3.61	3.46	0	0	0	0	0	0	>1.66	>5.27	>3.46	0	0	0	5	Physical	NO	Clean sand cap material > pen. Rippled. Small tubes at surface and organism tubes in farfield. RPD>pen
B8	A	6/19/2002	12:15	ST I to II	> 4 phi	3 to 2 phi	3 to 2 phi	SA.F	0	0	12.52	13.34	0.82	12.93	0	0	0	0	0	0	1.99	5.19	3.36	0	0	0	7	Physical	NO	S/M=Sand cap material layer over relic fine-grained dredged material. Amp stalks and other small tubes on surface. Shell material in farfield.
B8	C	6/19/2002	12:16	ST I on III	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	13.62	14.21	0.59	13.91	> 13.62	> 14.21	> 13.91	0	0	0	0.57	4.55	2.73	0	0	0	9	Physical	NO	Relic dredged material >pen. Flocculent layer at surface. Small tubes at surface. Voids at depth
B9	A	6/19/2002	12:24	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.7	4.02	1.32	3.36	0	0	0	0	0	0	1.35	3.98	2.56	0	0	0	5	Physical	NO	Clean homogenous sand cap material > pen. Sand waves in farfield. Small amount of shell material.
B9	B	6/19/2002	12:25	ST I to II	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.18	5.39	0.21	5.28	0	0	0	0	0	0	>5.18	>5.39	>5.28	0	0	0	8	Physical	NO	Clean sand cap material > pen. Small tubes and Amphipod stalks at surface. Lengthwise bisection of sand wave. RPD>pen
C1	A	6/18/2002	11:31	ST I on III	> 4 phi	3 to 2 phi	3 to 2 phi	SA.F	0	0	5.59	7	1.41	6.3	0	0	0	0	0	0	1.42	4.91	2.28	0	0	0	9	Physical	NO	S/M = fine clean cap sand over reduced sed @depth=patch of relic dredged material? Void at depth. Tube at surface. Sand wave.
C1	C	6/18/2002	11:33	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.M	0	0	2.16	3.95	1.79	3.06	0	0	0	0	0	0	-99	-99	-99.00	0	0	0	99	Physical	NO	Muddy brown ambient sand > pen (?). Smearing artifact from previous replicate. Shell material in farfield.
C10	B	6/19/2002	10:01	ST I	> 4 phi	3 to 2 phi	4 to 3 phi	UN.SS	0	0	2.41	2.8	0.39	2.61	0	0	0	0	0	0	>2.41	>2.8	>2.61	0	0	0	5	Physical	NO	Very fine brown ambient sand > pen. Solitary hydroids=Corymorpha pendula and small sand waves in farfield. RPD>p
C10	C	6/19/2002	10:02	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.86	4.16	1.3	3.51	0	0	0	0	0	0	>2.86	>4.16	>3.51	0	0	0	6	Physical	NO	Fine brown ambient sand > pen. Hydroids in farfield. Sand waves. RPD>pen
C11	A	6/19/2002	10:25	ST I	>4 phi	<-1 phi	1 to 0 phi	SA.G	0	0	4.32	4.91	0.59	4.61	0	0	0	0	0	0	1.49	2.7	1.60	0	0	0	4	Physical	NO	Poorly sorted coarse sand > pen. Probably ambient sed. Burrow at surface? Clay patch near surface. Shell frags
C11	B	6/19/2002	10:26	ST I	4 to 3 phi	1 to 0 phi	1 to 0 phi	SA.G	0	0	2	3.14	1.14	2.57	0	0	0	0	0	0	>2.0	>3.14	>2.57	0	0	0	5	Physical	NO	Brown, muddy, ambient coarse sand > pen. RPD > pen. Clay patches at and near surface. Small sand waves. Surf tubes
C12	A	6/19/2002	10:15	ST I to II	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.52	5.27	1.75	4.39	0	0	0	0	0	0	>3.52	>5.27	>4.39	0	0	0	7	Physical	NO	Clean cap sand > pen. Amphipod stalks at surface. Small ripple RPD>pen
C12	C	6/19/2002	10:16	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.91	4.38	1.47	3.64	0	0	0	0	0	0	>2.91	>4.38	>3.64	0	0	0	6	Physical	NO	Clean cap sand > pen. RPD>pen
C2	A	6/18/2002	11:41	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.02	4.61	1.59	3.82	0	0	0	0	0	0	>3.02	>4.61	>3.82	0	0	0	7	Physical	NO	Clean cap sand > pen. Dredged materail smear from previous station = artifact. Small ripple. RPD>pen
C2	C	6/18/2002	11:42	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.29	4.48	1.19	3.88	0	0	0	0	0	0	>3.29	>4.48	>3.88	0	0	0	7	Physical	NO	Clean cap sand > pen. Tubes and fecal casts in farfield. Slight ripple. RPD>pen
C3	B	6/18/2002	11:51	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3	8.23	5.23	5.61	0	0	0	0	0	0	>3.0	>8.23	>5.61	0	0	0	7	Physical	NO	Clean, homogenous cap sand > pen. Bisected sand wave. Surface tubes in farfield. RPD>pen
C3	C	6/18/2002	11:51	ST I	4 to 3 phi	2 to 1 phi	2 to 1 phi	SA.M	0	0	3.89	7.73	3.84	5.81	0	0	0	0	0	0	>3.89	>7.73	>5.81	0	0	0	7	Physical	NO	Sand cap material > pen. Rippled, RPD>pen
C4	A	6/18/2002	12:00	ST I	4 to 3 phi	2 to 1 phi	2 to 1 phi	SA.M	0	0	4.11	4.7	0.59	4.4	0	0	0	0	0	0	>4.11	>4.7	>4.4	0	0	0	7	Physical	NO	Clean, homogenous sand cap material > pen. Patch of gray fine-grained materail at surface. RPD>pen
C4	B	6/18/2002	12:00	ST I	4 to 3 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	4.3	7	2.7	5.65	0	0	0	0	0	0	0.93	4.29	2.59	0	0	0	5	Physical	NO	Sand cap material > pen. Amphipod stalk in farfield. Dissected sand wave.
C5	B	6/18/2002	12:09	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	3.32	5.45	2.13	4.38	0	0	0	0	0	0	>3.32	>5.45	>4.38	0	0	0	7	Physical	NO	Clean homogenous sand cap material > pen. Dissected sand wave. RPD>pen
C5	C	6/18/2002	12:10	ST I	3 to 2 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	3.32	5.14	1.82	4.23	0	0	0	0	0	0	>3.32	>5.14	>4.23	0	0	0	7	Physical	NO	Clean sand cap material > pen. Sand wave. Amphipod stalk in farfield. RPD>pen
C6	A	6/18/2002	09:52	ST II on III	> 4 phi	3 to 2 phi	> 4 phi	UN.SS	0	0	13.73	14.04	0.31	13.89	> 13.73	> 14.04	> 13.89	0	0	0	3.06	4.62	2.99	0	0	0	9	Physical	NO	Relic DM>pen; Voids at depth. Amp stalks and Nucula shells at surf. Sand component in sed near surface
C6	C	6/18/2002	09:53	ST II on III	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	14.32	14.98	0.66	14.65	> 14.32	> 14.98	> 14.65	0	0	0	1.07	5.83	2.54	0	0	0	9	Physical	NO	Relic DM>pen. reduced@depth, Void at depth, Amp stalks and other small tubes at surf. Smeared mud and drag down of RPD.
C7	A	6/18/2002	15:25	ST II to III	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	9.18	9.71	0.53	9.44	> 9.18	> 9.71	> 9.44	0	0	0	0.07	3.84	1.62	0	0	0	7	Physical	NO	Relic DM>pen; reduced@depth, amp tubes at surface. Stage III organism at depth.
C7	B	6/18/2002	15:26	ST I on III	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	8.36	8.73	0.37	8.55	> 8.36	> 8.73	> 8.55	0	0	0	2.85	4.27	2.52	0	0	0	9	Physical	NO	Relic DM>pen, reduced@depth, RPD measured through smearing artifact, voids and Stage III org @z. Shells@surf=Nucula?
C8	A	6/18/2002	15:17	ST I on III	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	10.29	10.84	0.55	10.57	> 10.29	> 10.84	> 10.57	0	0	0	0.78	4.91	2.49	0	0	0	9	Physical	NO	Relic DM>pen. reduced@depth, Nucula@surf? Voids at depth.
C8	C	6/18/2002	15:18	ST I	> 4 phi	4 to 3 phi	> 4 phi	UN.SI	0	0	13.66	13.95	0.29	13.81	> 13.66	> 13.95	> 13.81	0	0	0	0.07	2.99	0.73	0	0	0	2	Physical	NO	Relic DM>pen. reduced@depth, thin RPD, dense Stage 1 tubes farfield. Smear artifact from previous replicates.
C9	A	6/19/2002	10:07	ST I to II	0 to -1 phi	< -1 phi	< -1 phi	SA.G	0	0	6.07	6.82	0.75	6.45	0	0	0	0	0	0	-99	-99	-99.00	0	0	0	99	Physical	NO	Gravel > pen. Multiple Amphipod stalks at surface.
C9	C	6/19/2002	10:08	ST II on III	> 4 phi	4 to 3 phi	4 to 3 phi	UN.SS	0	0	3.2	5.93	2.73	4.57	0	0	0	0	0	0	>3.2	>5.93	>4.57	0	0	0	11	Physical	NO	Brown, muddy, ambient sand > pen. Void? Amphipod stalks at surface. RPD>per

Appendix A2

REMOTS Sediment-Profile Imaging Data from the South Reference Area, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface	Low	Comments
				Stage	Min	Max	Maj Mode	Habitat	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam		Roughness	DO	
SREF10	A	6/21/2002	16:12	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.8	4.16	0.36	3.98	0	0	0	0	0	0	>3.8	>4.16	>3.98	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Small sand waves. RPD>pen
SREF10	C	6/21/2002	16:14	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.18	5.14	0.96	4.66	0	0	0	0	0	0	>4.18	>5.14	>4.66	0	0	0	7	Physical	NO	Homogenous ambient sand. Slightly muddy. Shell material in farfield. Small sand waves. RPD>pen
SREF11	B	6/21/2002	15:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.79	7.8	1.01	7.3	0	0	0	0	0	0	1.49	3.63	2.34	0	0	0	5	Physical	NO	Homogenous ambient sand > pen. Slight ripple.
SREF11	C	6/21/2002	15:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.5	5.66	1.16	5.08	0	0	0	0	0	0	>4.5	>5.66	>5.08	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Organism at depth? Slight ripple, Shell frag farfield. RPD>pen
SREF14	B	6/21/2002	15:27	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.77	4.84	1.07	4.31	0	0	0	0	0	0	>3.77	>4.84	>4.31	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Sand dollars in farfield. RPD>pen
SREF14	C	6/21/2002	15:30	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.23	4.84	0.61	4.53	0	0	0	0	0	0	>4.23	>4.84	>4.53	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. RPD>pe
SREF16	B	6/21/2002	15:18	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.75	6.18	0.43	5.97	0	0	0	0	0	0	2.35	3.20	2.31	0	0	0	5	Physical	NO	Homogenous ambient sand > pen. Small tubes on surface.
SREF16	C	6/21/2002	15:19	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.66	4.21	1.55	3.43	0	0	0	0	0	0	>2.66	>4.21	>3.43	0	0	0	6	Physical	NO	Homogenous ambient sand > pen. RPD>pen Slight ripple.
SREF18	B	6/21/2002	15:13	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.32	4.71	0.39	4.52	0	0	0	0	0	0	>4.32	>4.71	>4.52	0	0	0	7	Physical	NO	Homogenous ambient sand > pen, shell material & possible surface orgs-far, RPD>pen
SREF18	C	6/21/2002	15:13	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.0	5.61	0.61	5.31	0	0	0	0	0	0	>5.0	>5.61	>5.31	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Possible organism tubes in farfield. RPD>pen
SREF20	A	6/21/2002	15:04	ST I	> 4 phi	3 to 2 phi	4 to 3 phi	SA.F	0	0	6.16	6.43	0.27	6.3	0	0	0	0	0	0	0.28	4.91	2.56	0	0	0	5	Physical	NO	Brown, ambient muddy fine sand, slightly reduced @ depth due to mud content, shell material @ surf.
SREF20	C	6/21/2002	15:07	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.88	6.34	0.46	6.11	0	0	0	0	0	0	>5.88	>6.34	>6.11	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Slight ripple in farfield. RPD>pen
SREF3	A	6/21/2002	16:02	ST I	4 to 3 phi	2 to 1 phi	2 to 1 phi	SA.M	0	0	7.89	8.36	0.47	8.12	0	0	0	0	0	0	>7.89	>8.36	>8.12	0	0	0	7	Physical	NO	Homogenous clean ambient medium sand > pen. Slight ripple. RPD>pen
SREF3	C	6/21/2002	16:03	ST I	4 to 3 phi	1 to 0 phi	2 to 1 phi	SA.M	0	0	2.89	5.73	2.84	4.31	0	0	0	0	0	0	>2.89	>5.73	>4.31	0	0	0	7	Physical	NO	Homogenous medium to coarse ambient sand >pen, shell material @ surf, sand wave, RPD>pen
SREF4	A	6/21/2002	14:53	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.55	3.8	0.25	3.67	0	0	0	0	0	0	>3.55	>3.8	>3.67	0	0	0	6	Physical	NO	Homogenous ambient sand > pen. Shell frags. Sand dollar in farfield. RPD>pen
SREF4	B	6/21/2002	14:54	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.41	6.66	0.25	6.53	0	0	0	0	0	0	>6.41	>6.66	>6.53	0	0	0	7	Physical	NO	Homogenous fine ambient sand > pen. RPD>pen
SREF5	A	6/21/2002	15:44	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.66	6.84	0.18	6.75	0	0	0	0	0	0	>6.66	>6.84	>6.75	0	0	0	7	Physical	NO	Homogenous ambient fine sand > pen. Sand dollars. RPD>pen
SREF5	B	6/21/2002	15:45	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.79	6.77	1.98	5.78	0	0	0	0	0	0	>4.79	>6.77	>5.78	0	0	0	7	Biogenic	NO	Homogenous ambient sand >pen, sand dollars, surf rough due to sand dollars,sand waves, RPD>pen
SREF8	A	6/21/2002	15:40	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.93	4.3	0.37	4.12	0	0	0	0	0	0	>3.93	>4.3	>4.12	0	0	0	7	Biogenic	NO	Homogenous ambient fine sand > pen. Sand dollar. RPD>pen
SREF8	B	6/21/2002	15:41	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.48	7.05	0.57	6.77	0	0	0	0	0	0	1.35	3.84	2.20	0	0	0	4	Physical	NO	Homogenous ambient sand > pen. Slightly muddy and slightly reduced@dep

Appendix B
Benthic Taxonomy Results

Table B-1.
Number of individuals per m^2 of each taxon found at the five 1993 Dioxin Capping Project Mound stations

	Station				
Taxon Name	A19	A23	A5	A9	B8
Nucula proxima	775	11325	5350	25	24850
Pellucistoma (LPIL)	50	750	1175	125	475
Aricidea catherinae	0	125	450	75	575
Scoletoma (LPIL)	0	75	25	0	1000
Polygordius (LPIL)	0	375	525	25	100
Monticellina dorsobranchialis	25	25	0	0	850
Diastylis polita	150	100	200	200	0
Nephtys picta	275	50	200	50	75
Exogone hebes	275	25	0	325	0
Edotea triloba	100	0	125	275	25
Pitar morrhuanus	0	150	100	0	275
Mancocuma stellifera	75	150	75	200	0
Tellina agilis	0	75	75	0	275
Dulichia porrecta	25	75	50	0	200
Tubificidae (LPIL)	0	75	175	75	25
Levinsenia gracilis	0	0	50	0	225
Nephtys incisa	0	0	0	0	275
Mediomastus (LPIL)	0	0	175	0	75
Aricidea (LPIL)	0	25	50	25	125
Eusarsiella zostericola	25	75	0	0	125
Mediomastus ambiseta	0	0	225	0	0
Spiophanes bombyx	25	50	75	0	75
Pandora arenosa	25	75	75	0	25
Cardiidae (LPIL)	0	0	25	0	150
Chiridotea tuftsi	0	75	25	75	0
Glycera (LPIL)	0	50	75	50	0
Cirratulidae (LPIL)	0	0	0	0	150
Dorvilleidae (LPIL)	0	0	0	50	100
Rhynchocoela (LPIL)	50	0	25	50	0
Scoletoma ernesti	75	50	0	0	0
Scoletoma verrilli	0	0	0	0	125
Spio filicornis	0	0	0	0	125
Yoldia limatula	0	0	0	0	125
Asabellides oculata	0	25	0	75	0
Bivalvia (LPIL)	25	50	25	0	0
Nephtys (LPIL)	0	0	100	0	0
Prionospio steenstrupi	0	0	0	0	100
Rhepoxynius epistomus	0	25	0	75	0
Tharyx acutus	0	25	0	0	75
Apoprionospio pygmaea	0	0	75	0	0
Hippomedon serratus	50	0	0	25	0
Maldanidae (LPIL)	25	0	0	50	0
Naticidae (LPIL)	25	25	0	25	0
Ninoe nigripes	25	0	0	0	50

Table B-1. (continued)
Number of individuals per m^2 of each taxon found at the five 1993 Dioxin Capping Project Mound stations

Taxon Name	Station				
	A19	A23	A5	A9	B8
Spionidae (LPIL)	0	0	0	0	75
Tellina (LPIL)	0	0	0	75	0
Unciola irrorata	0	0	0	25	50
Ampelisca abdita	0	0	0	0	50
Ampelisca vadorum	0	0	50	0	0
Aricidea wassi	0	0	0	50	0
Astarte borealis	0	0	0	0	50
Axiothella mucosa	0	0	0	50	0
Cerastoderma pinnulatum	25	25	0	0	0
Crangon septemspinosa	0	25	25	0	0
Ensis (LPIL)	0	0	25	25	0
Ilyanassa trivittata	50	0	0	0	0
Lyonsia hyalina	25	25	0	0	0
Pherusa affinis	25	0	0	0	25
Photis (LPIL)	0	0	0	0	50
Scalibregma inflatum	50	0	0	0	0
Spisula solidissima	25	0	0	25	0
Sthenelais limicola	0	50	0	0	0
Ampelisca (LPIL)	0	25	0	0	0
Calyptraeidae (LPIL)	0	0	25	0	0
Chaetozone setosa	0	25	0	0	0
Cossura soyeri	0	0	0	0	25
Fimbriosthenelais minor	0	0	0	25	0
Glycera robusta	0	0	25	0	0
Haminoea solitaria	0	25	0	0	0
Leitoscoloplos robustus	0	25	0	0	0
Leptocheirus pinguis	0	0	0	0	25
Lucinidae (LPIL)	0	0	0	0	25
Nassariidae (LPIL)	0	0	25	0	0
Pagurus (LPIL)	0	25	0	0	0
Parougia caeca	25	0	0	0	0
Photis macrocoxa	0	25	0	0	0
Scoletoma acicularum	0	0	25	0	0
Streblospio benedicti	0	25	0	0	0
Turbellaria (LPIL)	0	25	0	0	0
Veneridae (LPIL)	25	0	0	0	0

Table B-2.
Number of individuals per m^2 of each taxon found at the three South Reference Area stations

	Station		
Taxon Name	S4	S8	S14
Tubificidae (LPIL)	425	75	1350
Exogone hebes	150	25	1025
Polygordius (LPIL)	325	75	575
Pellucistoma (LPIL)	50	225	650
Nephtys picta	0	450	275
Mancocuma stellifera	225	175	75
Caulleriella sp. J	175	225	25
Aricidea catherinae	0	150	175
Rhepoxynius epistomus	100	150	50
Rhynchocoela (LPIL)	125	75	75
Tanaissus psammophilus	250	25	0
Monticellina dorsobranchialis	25	0	225
Nucula proxima	50	0	200
Unciola (LPIL)	250	0	0
Chiridotea tuftsi	0	0	225
Aricidea (LPIL)	200	0	0
Syllides longocirrata	25	50	100
Tellinidae (LPIL)	0	175	0
Tellina agilis	150	0	0
Chaetozone setosa	0	25	100
Hippomedon serratus	75	25	25
Pandora arenosa	50	50	25
Parougia caeca	25	25	75
Scoletoma acicularum	50	50	25
Glyceridae (LPIL)	100	0	0
Spiophanes bombyx	25	0	75
Cirratulidae (LPIL)	75	0	0
Edotea triloba	50	25	0
Maldanidae (LPIL)	75	0	0
Ampharete acutifrons	50	0	0
Aricidea wassi	0	0	50
Astarte borealis	0	50	0
Cerastoderma pinnulatum	50	0	0
Dulichia porrecta	0	50	0
Mytilus edulis	25	25	0
Nephtyidae (LPIL)	50	0	0
Nephtys (LPIL)	50	0	0
Paraonidae (LPIL)	25	25	0
Pitar morrhuanus	50	0	0
Scalibregma inflatum	0	0	50
Tellina (LPIL)	0	0	50
Ampelisca (LPIL)	25	0	0
Ampharetidae (LPIL)	0	25	0
Bivalvia (LPIL)	0	0	25
Byblis (LPIL)	0	0	25
Diastylis polita	0	0	25
Drilonereis longa	0	0	25
Echinarachnius parma	0	25	0
Echinoidea (LPIL)	0	25	0
Euchone elegans	25	0	0
Fimbriosthenelais minor	25	0	0
Glycera robusta	0	25	0
Ilyanassa trivittata	0	25	0
Lumbrinerides acuta	25	0	0
Mytilidae (LPIL)	0	25	0
Pitar (LPIL)	0	0	25
Protohaustorius wigleyi	25	0	0
Scoloplos armiger	0	25	0
Spionidae (LPIL)	25	0	0
Spisula solidissima	25	0	0

Appendix C
Core Analysis Results

Appendix C-1
Core Logs

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002

Core: G2

Total Core Length: 286 cm

Longitude: -73.84491

Latitude: 40.37086

Cap Interface: 230 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0	0-230	motteled dark gray and tan, no odor, moist, hard, SAND					
	-4							
	-8							
	-12							
	-16							
	-20							
	-24							
	-28							
	-32							
	-36							
	-40							
	-44							
	-48							
	-52							
	-56							
	-60							
	-64							
	-68							

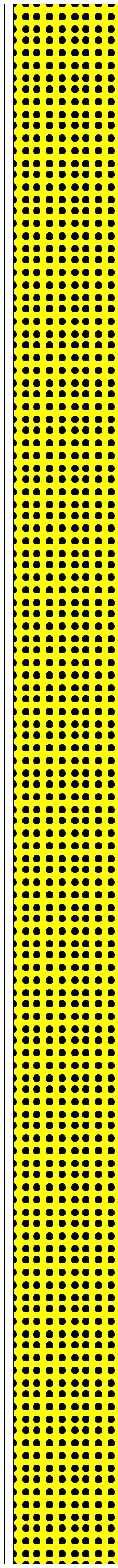
The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G2
Total Core Length: 286 cm

Longitude: -73.84491
Latitude: 40.37086
Cap Interface: 230 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

-72
-76
-80
-84
-88
-92
-96
-100
-104
-108
-112
-116
-120
-124
-128
-132
-136
-140



The 2002 Survey of the 1993 Dioxin Mound

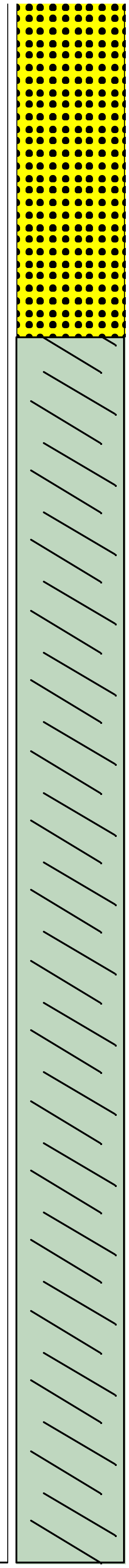
Survey: HARS Coring 2002
Core: G2
Total Core Length: 286 cm
Longitude: -73.84491
Latitude: 40.37086
Cap Interface: 230 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis		Lithology
	-144					
	-148					
	-152					
	-156					
	-160					
	-164					
	-168					
	-172					
	-176					
	-180					
	-184					
	-188					
	-192					
	-196					
				197-203	PCDD/PCDF, TOC	
				199-201	Bulk Density, Water Content	
	-200					
	-204					
	-208					
				209-211	Bulk Density, Water Content	
	-212					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G2
Total Core Length: 286 cm

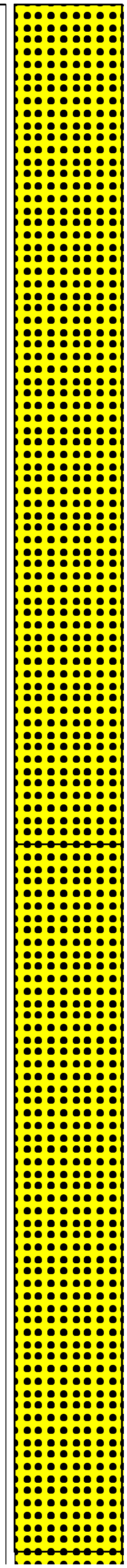
Longitude: -73.84491
Latitude: 40.37086
Cap Interface: 230 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-216, -220, -224, -228, -232, -236, -240, -244, -248, -252, -256, -260, -264, -268, -272, -276, -280, -284			216-224	black striations of UDM	217-223	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content	
		230-286	black with dark brown motteled, petroleum odor, moist, firm-hard, CLAY	230-250	sand drag down along liner - minimal	237-243	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content	
						249-251	Bulk Density, Water Content	
						257-263	PCDD/PCDF, TOC	
						259-261	Bulk Density, Water Content	
						269-271	Bulk Density, Water Content	
				273-283	vertical band of tan to brown clay and sand	279-281	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G3
Total Core Length: 280 cm

Longitude: -73.84595
Latitude: 40.36915
Cap Interface: 258 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0 to -68	0-38	tan to dark gray, no odor, moist, hard, SAND					
		38-70	tan, no odor, moist, hard, SAND					

Depth scale: 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60, -64, -68

The 2002 Survey of the 1993 Dioxin Mound

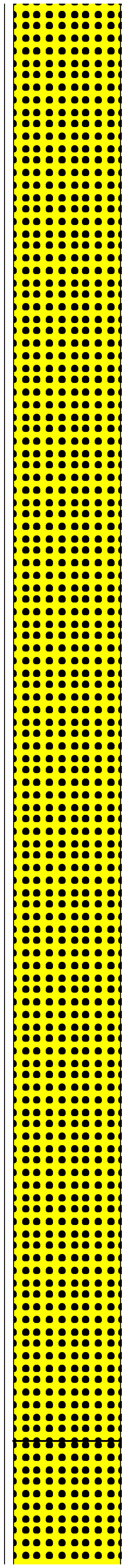
Survey: HARS Coring 2002
Core: G3
Total Core Length: 280 cm

Longitude: -73.84595
Latitude: 40.36915
Cap Interface: 258 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis	Lithology
	-72 -76 -80 -84 -88 -92 -96 -100 -104 -108 -112 -116	70-118	banded dark gray and tan, no odor, moist, hard, SAND				
	-120 -124 -128 -132 -136 -140	118-206	banded dark gray and tan, slight petroleum odor, moist, hard, SAND				

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G3
Total Core Length: 280 cm
Longitude: -73.84595
Latitude: 40.36915
Cap Interface: 258 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis	Lithology
	-144 -148 -152 -156 -160 -164 -168 -172 -176 -180 -184 -188 -192 -196 -200 -204 -208	206-258	black, petroleum odor, moist, hard, SAND				

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G3
Total Core Length: 280 cm

Longitude: -73.84595
Latitude: 40.36915
Cap Interface: 258 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology

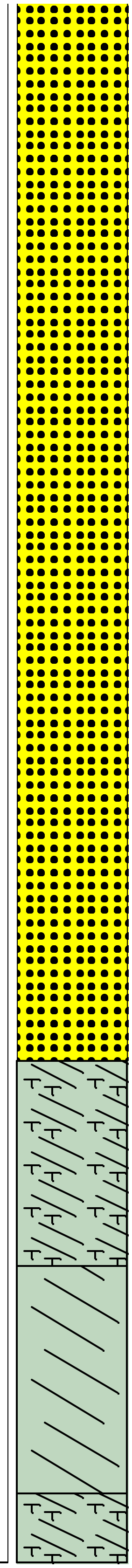
Depth (cm): -212, -216, -220, -224, -228, -232, -236, -240, -244, -248, -252, -256, -260, -264, -268, -272, -276, -280

Major Interval

Interval	Description
258-267	black, petroleum odor, moist, soft-firm, SILTY CLAY
267-277	red, no odor, moist, firm-hard, CLAY
277-280	black, petroleum odor, moist, soft-firm, SILTY CLAY

Analysis

Interval	Analysis
225-231	PCDD/PCDF, TOC
227-229	Bulk Density, Water Content
237-239	Bulk Density, Water Content
245-251	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content
265-261	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content
275-281	PCDD/PCDF, TOC
277-279	Bulk Density, Water Content



The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G4
Total Core Length: 224 cm

Longitude: -73.84675
Latitude: 40.36795
Cap Interface: 142 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24	0-28	grayish-brown, marine odor, moist, hard, SAND					
	-28, -32, -36, -40, -44, -48, -52, -56	28-73	gray with black bands, marine odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: **HARS Coring 2002**
Core: **G4**
Total Core Length: **224 cm**

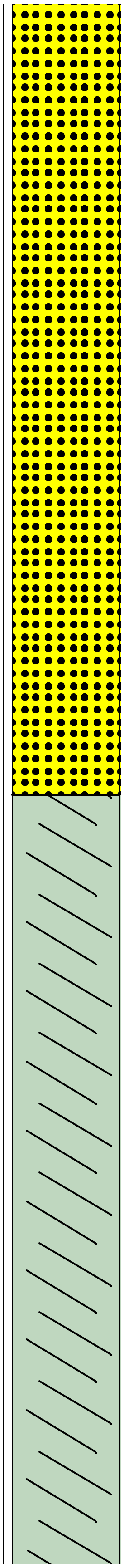
Longitude: -73.84675
Latitude: 40.36795
Cap Interface: 142 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-60, -64, -68, -72, -76, -80, -84, -88, -92, -96, -100, -104, -108, -112	73-142	dark gray with black bands, marine odor, moist, hard, SAND			111-113	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G4
Total Core Length: 224 cm

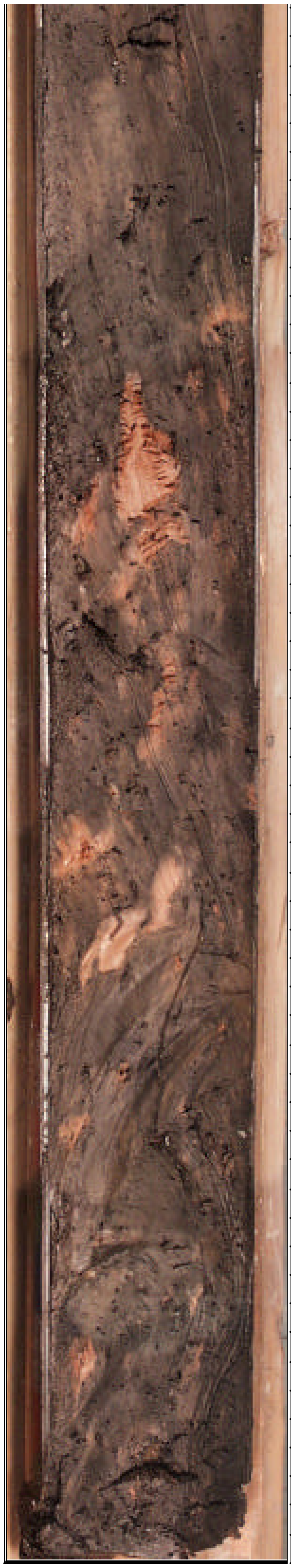
Longitude: -73.84675
Latitude: 40.36795
Cap Interface: 142 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-116							
	-120							
						121-123	Bulk Density, Water Content	
	-124							
	-128							
						129-135	Bulk Density, Grain Size - Sieve Only, Water Content	
	-132							
	-136							
	-140							
		142-224	black mottled with red, petroleum odor, moist, firm, CLAY					
	-144							
	-148							
						149-155	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content	
	-152							
	-156							
	-160							
						161-163	Bulk Density, Water Content	
	-164							
	-168							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G4
Total Core Length: 224 cm

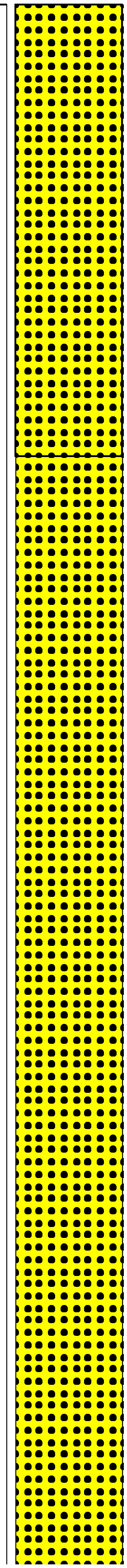
Longitude: -73.84675
Latitude: 40.36795
Cap Interface: 142 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis		Lithology
	-172			171-173	Bulk Density, Water Content	
	-176					
	-180			181-183	Bulk Density, Water Content	
	-184					
	-188					
	-192			191-193	Bulk Density, Water Content	
	-196					
	-200			201-203	Bulk Density, Water Content	
	-204					
	-208					
	-212			211-213	Bulk Density, Water Content	
	-216					
	-220					
	-224					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G5
Total Core Length: 220 cm

Longitude: -73.84788
Latitude: 40.3673
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52	0-16	brownish-gray, marine odor, moist, hard, SAND					
		16-89	gray with black bands, marine odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

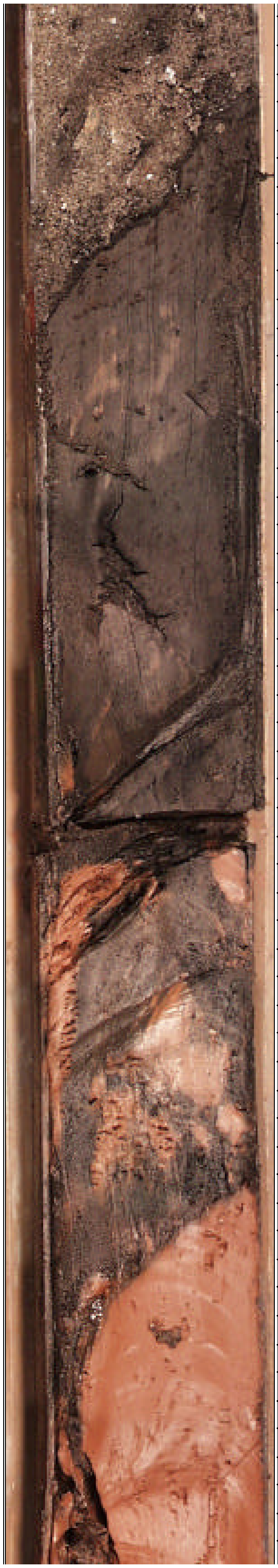
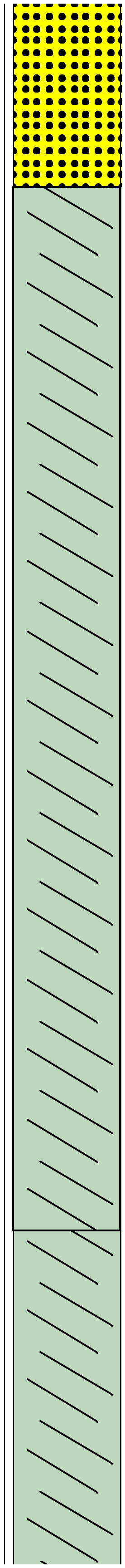
Survey: HARS Coring 2002
Core: G5
Total Core Length: 220 cm

Longitude: -73.84788
Latitude: 40.3673
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-56							
	-60							
	-64							
	-68							
	-72							
	-76							
	-80							
	-84							
						86-88	Bulk Density, Water Content	
	-88							
		89-117	dark gray with black bands, marine odor, moist, hard, SAND					
	-92							
	-96					96-98	Bulk Density, Water Content	
	-100							
	-104					104-110	Bulk Density, Grain Size - Sieve Only, Water Content	
	-108							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G5
Total Core Length: 220 cm
Longitude: -73.84788
Latitude: 40.3673
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-112, -116, -120, -124, -128, -132, -136, -140, -144, -148, -152, -156, -160, -164	117-154	black mottled with red, petroleum odor, moist, firm, CLAY			124-130	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content	
						136-138	Bulk Density, Water Content	
						146-148	Bulk Density, Water Content	
		154-220	red, slight petroleum odor, moist, firm, CLAY			156-158	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G5
Total Core Length: 220 cm

Longitude: -73.84788
Latitude: 40.3673
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-168					166-168	Bulk Density, Water Content	
	-172							
	-176					176-178	Bulk Density, Water Content	
	-180							
	-184							
	-188					186-188	Bulk Density, Water Content	
	-192							
	-196							
	-200							
	-204							
	-208							
	-212							
	-216			217-220	black clay			
	-220							

The 2002 Survey of the 1993 Dioxin Mound

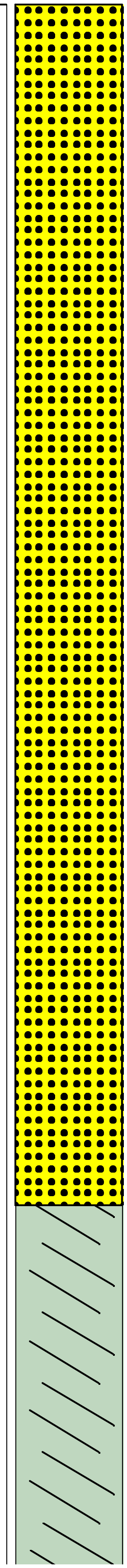
Survey: HARS Coring 2002
Core: G6
Total Core Length: 300 cm

Longitude: -73.84995
Latitude: 40.36576
Cap Interface: 59 cm

Core Photo | **Depth (cm)** | **Major Interval** | **Sub-Interval** | **Analysis** | **Lithology**

Depth (cm): 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60, -64, -68, -72, -76

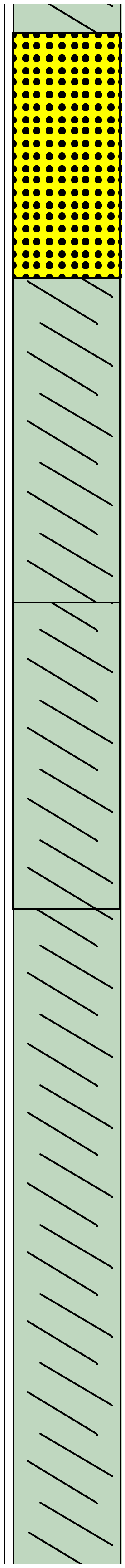
Major Interval	Description	Sub-Interval	Description	Analysis Interval	Analysis
0-59	dark gray, no odor, moist, hard, SAND with Shell Fragments				
				28-30	Bulk Density, Water Content
				38-40	Bulk Density, Water Content
		42-46	shell		
				46-52	Bulk Density, Grain Size - Sieve Only, Water Content
59-78	mottled, black with red , petroleum odor, moist, soft-firm, CLAY				
				68-70	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content



The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G6
Total Core Length: 300 cm

Longitude: -73.84995
Latitude: 40.36576
Cap Interface: 59 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-80 -84 -88 -92 -96 -100 -104 -108 -112 -116 -120 -124 -128 -132 -136 -140 -144 -148 -152							
		78-90	black , petroleum odor, moist, firm-hard, SAND with Clay			78-80	Bulk Density, Water Content	
						88-90	Bulk Density, Water Content	
		90-106	mottled black and red, petroleum odor, moist, soft-firm, CLAY			98-100	Bulk Density, Water Content	
		106-121	mottled black and red, petroleum odor, wet-moist, soft, CLAY with Gravel			108-110	Bulk Density, Water Content	
						118-120	Bulk Density, Water Content	
		121-157	mottled red and black, marine odor, moist, hard, CLAY with Gravel			128-130	Bulk Density, Water Content	
				132-136	rock			

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G6
Total Core Length: 300 cm
Longitude: -73.84995
Latitude: 40.36576
Cap Interface: 59 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval	Analysis	Lithology
	-156 -160 -164 -168 -172 -176 -180 -184 -188 -192 -196 -200 -204 -208 -212 -216 -220 -224 -228	157-242	mottled black and red, petroleum odor, moist, soft-firm, CLAY with Gravel			

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002

Core: G6

Total Core Length: 300 cm

Longitude: -73.84995

Latitude: 40.36576

Cap Interface: 59 cm

Depth (cm): -232, -236, -240, -244, -248, -252, -256, -260, -264, -268, -272, -276, -280, -284, -288, -292, -296, -300

Major Interval		Sub-Interval		Analysis		Lithology
242-300	mottled black and red, petroleum odor, moist, firm, CLAY with Gravel	242-247	rock			

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G7
Total Core Length: 246 cm

Longitude: -73.85257
Latitude: 40.36371
Cap Interface: >246cm

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Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60	0-199	dark gray, marine odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G7
Total Core Length: 246 cm

Longitude: -73.85257
Latitude: 40.36371
Cap Interface: >246cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G7
Total Core Length: 246 cm

Longitude: -73.85257
Latitude: 40.36371
Cap Interface: >246cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-124 -128 -132 -136 -140 -144 -148 -152 -156 -160 -164 -168 -172 -176 -180 -184							
				160-163	shell			
						168-170	Bulk Density, Water Content	
						178-180	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: G7
Total Core Length: 246 cm

Longitude: -73.85257
Latitude: 40.36371
Cap Interface: >246cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-188, -192, -196, -200, -204, -208, -212, -216, -220, -224, -228, -232, -236, -240, -244					186-192	Bulk Density, Grain Size - Sieve Only, Water Content	
				194-195	shell			
		199-246	black, petroleum odor, moist, hard, Clayey SAND					
						206-212	Bulk Density, Grain Size - w/Hydrometer, Specific Gravity, Water Content	
				212-220	dark reddish-brown clayey sand			
						218-220	Bulk Density, Water Content	
				220-227	gray clay			
						228-230	Bulk Density, Water Content	
						238-240	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: **HARS Coring 2002**
Core: **GX**
Total Core Length: **276 cm**

Longitude: -73.85117
Latitude: 40.36482
Cap Interface: >276cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0 -4 -8 -12 -16 -20 -24 -28 -32 -36 -40 -44 -48 -52 -56 -60 -64 -68	0-137	dark gray mottled with brown, marine odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: GX
Total Core Length: 276 cm

Longitude: -73.85117
Latitude: 40.36482
Cap Interface: >276cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis	Lithology
	-72						
	-76						
	-80						
	-84						
	-88						
	-92						
	-96						
	-100						
	-104						
	-108						
	-112						
	-116						
	-120						
	-124						
	-128						
	-132						
	-136						
	-140	137-218	dark gray mottled with black, marine odor, moist, hard, SAND				

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: GX
Total Core Length: 276 cm

Longitude: -73.85117
Latitude: 40.36482
Cap Interface: >276cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval		Analysis		Lithology

Sub-Interval		Analysis	
188-192	shell	190-192	Bulk Density, Water Content
197-201	shell	200-202	Bulk Density, Water Content
		208-214	Bulk Density, Grain Size - Sieve Only, Water Content

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: GX
Total Core Length: 276 cm

Longitude: -73.85117
Latitude: 40.36482
Cap Interface: >276cm

Core Photo | **Depth** (cm) | **Major Interval** | **Sub-Interval** | **Analysis** | **Lithology**

Depth (cm): -216, -220, -224, -228, -232, -236, -240, -244, -248, -252, -256, -260, -264, -268, -272, -276

Major Interval	Description
218-221	black, marine odor, moist, hard, SAND
221-241	black, petroleum odor, moist, firm, CLAY
241-261	dark gray, petroleum odor, moist, hard, SAND with Gravel
261-276	olive gray, marine odor, moist, hard, SAND

Sub-Interval	Description
227-228	black sand with petroleum odor
271-272	black sandy clay

Analysis Interval	Analysis
228-234	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content
240-242	Bulk Density, Water Content
250-252	Bulk Density, Water Content
260-262	Bulk Density, Water Content
270-272	Bulk Density, Water Content

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H2
Total Core Length: 280 cm

Longitude: -73.85134
Latitude: 40.36943
Cap Interface: 186 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60, -64, -68	0-183	dark gray, no odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H2
Total Core Length: 280 cm

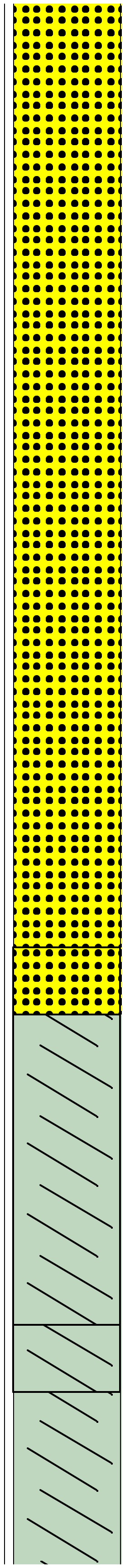
Longitude: -73.85134
Latitude: 40.36943
Cap Interface: 186 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H2
Total Core Length: 280 cm

Longitude: -73.85134
Latitude: 40.36943
Cap Interface: 186 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-144 -148 -152 -156 -160 -164 -168 -172 -176 -180 -184 -188 -192 -196 -200 -204 -208	183-186	black, petroleum odor, moist, hard, SAND	182-185	shell	155-157	Bulk Density, Water Content	
		186-200	black, petroleum odor, moist, soft-firm, CLAY			165-167	Bulk Density, Water Content	
		200-203	black, petroleum odor, wet, very soft, CLAY			173-179	Bulk Density, Grain Size - Sieve Only, Water Content	
		203-220	black, petroleum odor, wet, soft, Sandy CLAY			193-199	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content	
						205-207	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H2
Total Core Length: 280 cm
Longitude: -73.85134
Latitude: 40.36943
Cap Interface: 186 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-212							
	-216					215-217	Bulk Density, Water Content	
	-220	220-230	black, petroleum odor, moist, firm, CLAY					
	-224					225-227	Bulk Density, Water Content	
	-228							
	-232	230-280	red, no odor, moist, hard, CLAY					
	-236					235-237	Bulk Density, Water Content	
	-240							
	-244					245-247	Bulk Density, Water Content	
	-248							
	-252							
	-256					255-257	Bulk Density, Water Content	
	-260							
	-264							
	-268							
	-272			272-280	dark gray, no odor, moist, soft, sandy CLAY			
	-276							
	-280							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H3
Total Core Length: 243 cm

Longitude: -73.8488
Latitude: 40.36687
Cap Interface: 162 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24	0-28	dark gray to tan, no odor, moist, hard, SAND					
	-28, -32, -36, -40, -44, -48, -52, -56, -60	28-99	dark gray, slight marine odor, moist, hard, Clayey SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H3
Total Core Length: 243 cm

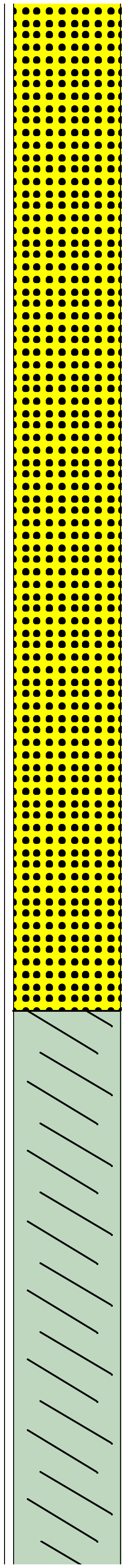
Longitude: -73.8488
Latitude: 40.36687
Cap Interface: 162 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval	Analysis	Lithology
	-64, -68, -72, -76, -80, -84, -88, -92, -96, -100, -104, -108, -112, -116, -120	99-162	dark gray to black, petroleum odor, moist, hard, Clayey SAND			

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H3
Total Core Length: 243 cm

Longitude: -73.8488
Latitude: 40.36687
Cap Interface: 162 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-124, -128, -132, -136, -140, -144, -148, -152, -156, -160, -164, -168, -172, -176, -180							
						129-135	PCDD/PCDF, TOC	
						131-133	Bulk Density, Water Content	
						141-143	Bulk Density, Water Content	
						149-155	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content	
		162-243	black, petroleum odor, moist, firm-hard, CLAY					
				166-168	wood chip			
						169-175	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content	
						181-183	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H3
Total Core Length: 243 cm
Longitude: -73.8488
Latitude: 40.36687
Cap Interface: 162 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

Depth (cm): -184, -188, -192, -196, -200, -204, -208, -212, -216, -220, -224, -228, -232, -236, -240

Sub-Interval

Interval	Description
217-219	red clay band

Analysis

Interval	Analysis
189-195	PCDD/PCDF, TOC
191-193	Bulk Density, Water Content
201-203	Bulk Density, Water Content
211-213	Bulk Density, Water Content
221-223	Bulk Density, Water Content
231-233	Bulk Density, Water Content

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H4
Total Core Length: 272 cm

Longitude: -73.84588
Latitude: 40.36402
Cap Interface: 188 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0 to -68	0-38	dark gray, no odor, moist, hard, SAND					
		38-56	tan, no odor, moist, hard, SAND					
		56-142	dark gray and tan, no odor, moist, hard, SAND					

Depth scale (cm): 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60, -64, -68

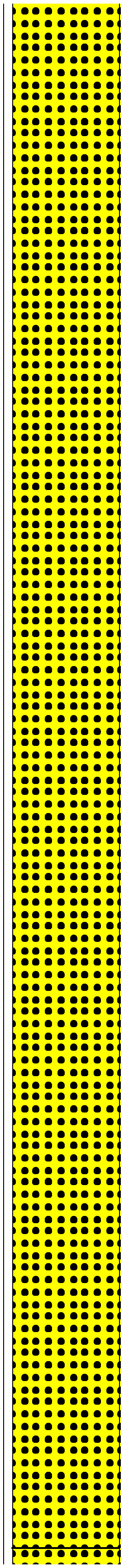
The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H4
Total Core Length: 272 cm

Longitude: -73.84588
Latitude: 40.36402
Cap Interface: 188 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

-72
-76
-80
-84
-88
-92
-96
-100
-104
-108
-112
-116
-120
-124
-128
-132
-136
-140



The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H4
Total Core Length: 272 cm
Longitude: -73.84588
Latitude: 40.36402
Cap Interface: 188 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-144 to -212	142-188	black and dark gray, slight petroleum odor, moist, hard, SAND			159-165	PCDD/PCDF, TOC	
						161-163	Bulk Density, Water Content	
						171-173	Bulk Density, Water Content	
						179-185	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content	
		188-208	black, petroleum odor, moist, firm-hard, CLAY			199-205	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content	
		208-222	banded brown and black, slight petroleum odor, moist, firm-hard, Sandy Silty CLAY			211-213	Bulk Density, Water Content	

Depth scale (cm): -144, -148, -152, -156, -160, -164, -168, -172, -176, -180, -184, -188, -192, -196, -200, -204, -208, -212

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: H4
Total Core Length: 272 cm
Longitude: -73.84588
Latitude: 40.36402
Cap Interface: 188 cm

Depth (cm)	Major Interval		Sub-Interval		Analysis	
-216 to -272	222-266	black, petroleum odor, moist, firm-hard, CLAY	233-243	rock	219-225	PCDD/PCDF, TOC
			243-246	black, slight petroleum odor, moist, firm-hard, clayey SAND	221-223	Bulk Density, Water Content
	266-272	dark brown, petroleum odor, moist, firm-hard, Sandy SILTY CLAY			231-233	Bulk Density, Water Content
					246-248	Bulk Density, Water Content
					251-253	Bulk Density, Water Content
					261-263	Bulk Density, Water Content

Depth scale: -216, -220, -224, -228, -232, -236, -240, -244, -248, -252, -256, -260, -264, -268, -272

Core Photo | Depth (cm) | Major Interval | Sub-Interval | Analysis | Lithology

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HS
Total Core Length: 234 cm

Longitude: -73.84663
Latitude: 40.36503
Cap Interface: 163 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0 to -56	0-26	light to dark gray, no odor, moist, hard, SAND					
		26-55	light to dark gray, with iron oxide and black lenses, no odor, moist, hard, SAND					
		55-163	dark gray with black streaks, no odor, moist, hard, SAND					

Depth scale: 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HS
Total Core Length: 234 cm

Longitude: -73.84663
Latitude: 40.36503
Cap Interface: 163 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology

-60
-64
-68
-72
-76
-80
-84
-88
-92
-96
-100
-104
-108
-112
-116

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HS
Total Core Length: 234 cm

Longitude: -73.84663
Latitude: 40.36503
Cap Interface: 163 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-120							
	-124							
	-128							
	-132					132-134	Bulk Density, Water Content	
	-136							
	-140							
	-144					142-144	Bulk Density, Water Content	
	-148							
	-152					150-156	Bulk Density, Grain Size - Sieve Only, Water Content	
	-156							
	-160							
	-164	163-182	black, petroleum odor, moist, firm, CLAY					
	-168							
	-172					170-176	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content	
	-176							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002

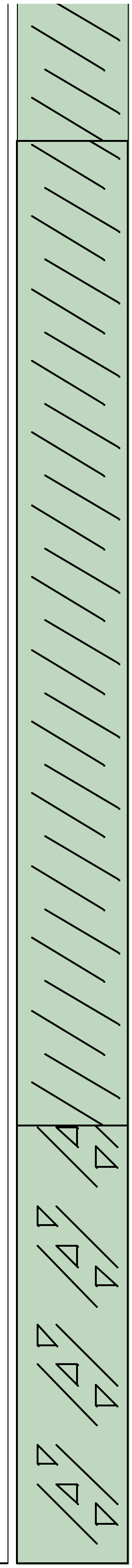
Core: HS

Total Core Length: 234 cm

Longitude: -73.84663

Latitude: 40.36503

Cap Interface: 163 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-180							
	-184	182-218	olive brown, petroleum odor, wet, very soft, Silty CLAY with Gravel			182-184	Bulk Density, Water Content	
	-188							
	-192					192-194	Bulk Density, Water Content	
	-196							
	-200							
	-204					202-204	Bulk Density, Water Content	
	-208			208-210	red clay nodule			
	-212					212-214	Bulk Density, Water Content	
	-216							
	-220	218-234	olive brown, petroleum odor, wet, very soft, CLAY AND ROCK	218-234	light gray, yellowish-red, and black clay nodules			
	-224							
	-228							
	-232							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HT
Total Core Length: 265 cm

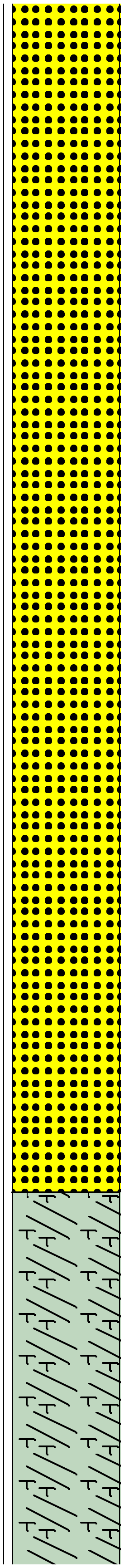
Longitude: -73.84783
Latitude: 40.36605
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52	0-55	gray to tanish, no odor, moist, hard, SAND					
	-56, -60, -64	55-117	dark gray to black, slight organic odor, moist, hard, SAND					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HT
Total Core Length: 265 cm

Longitude: -73.84783
Latitude: 40.36605
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-68 to -132	117-185	black, petroleum odor, moist, soft-firm, SILTY CLAY	80-82	rock	84-90	PCDD/PCDF, TOC	
				85-89	shell	86-88	Bulk Density, Water Content	
						96-98	Bulk Density, Water Content	
						104-110	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content	
						114-120	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HT
Total Core Length: 265 cm
Longitude: -73.84783
Latitude: 40.36605
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-136					136-138	Bulk Density, Water Content	
	-140							
	-144					144-150	PCDD/PCDF, TOC	
						146-148	Bulk Density, Water Content	
	-148							
	-152							
	-156					156-158	Bulk Density, Water Content	
				157-158	red clay nodule			
	-160							
	-164							
	-168					166-168	Bulk Density, Water Content	
	-172							
	-176							
	-180							
	-184							
		185-227	red, organic/petroleum odor, moist, soft-firm, CLAY					
	-188					186-188	Bulk Density, Water Content	
	-192							
	-196					196-198	Bulk Density, Water Content	

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HT
Total Core Length: 265 cm

Longitude: -73.84783
Latitude: 40.36605
Cap Interface: 117 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-200 -204 -208 -212 -216 -220 -224 -228 -232 -236 -240 -244 -248 -252 -256 -260 -264	227-265	black, petroleum odor, moist, soft-firm, Silty SANDY CLAY					

The 2002 Survey of the 1993 Dioxin Mound

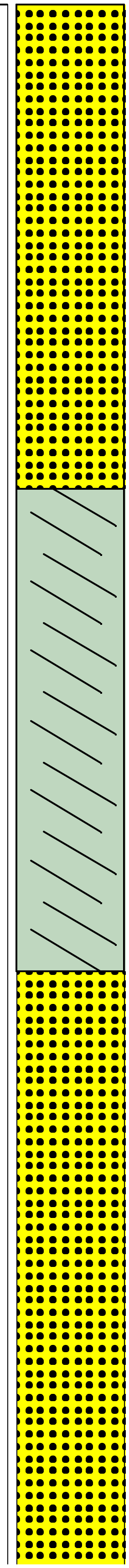
Survey: HARS Coring 2002
Core: HU
Total Core Length: 192 cm

Longitude: -73.84945
Latitude: 40.36777
Cap Interface: 50 cm

Core Photo | **Depth (cm)** | **Major Interval** | **Sub-Interval** | **Analysis** | **Lithology**

Depth (cm): 0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48

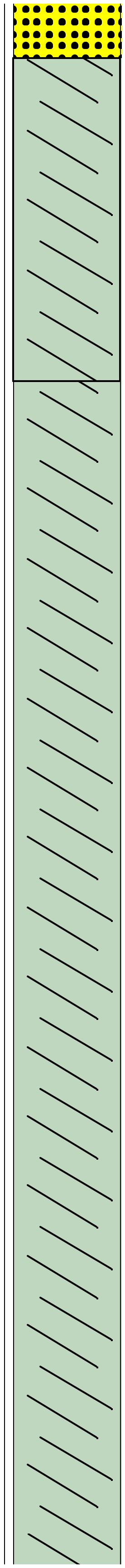
Major Interval	Description	Sub-Interval	Description	Analysis Interval	Analysis
0-15	dark gray, marine odor, moist, firm-hard, SAND				
15-30	black, petroleum odor, moist, firm, CLAY			19-21	Bulk Density, Water Content
				29-31	Bulk Density, Water Content
30-50	dark gray, marine odor, moist, hard, SAND			37-43	Bulk Density, Grain Size - Sieve Only, Water Content



The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HU
Total Core Length: 192 cm

Longitude: -73.84945
Latitude: 40.36777
Cap Interface: 50 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-52, -56, -60, -64, -68, -72, -76, -80, -84, -88, -92, -96	50-60	black, petroleum odor, moist, firm, CLAY			54-60	Shear Strength	
						57-63	Bulk Density, Grain Size - w/Hydrometer, Specific Gravity, Water Content	
		60-192	red, no odor, moist, firm, CLAY	61-66	black clay with petroleum odor			
						69-71	Bulk Density, Water Content	
				71-74	black clay withy petroleum odor			
						79-81	Bulk Density, Water Content	
						89-91	Bulk Density, Water Content	
				91-96	black clay with petroleum odor			

The 2002 Survey of the 1993 Dioxin Mound

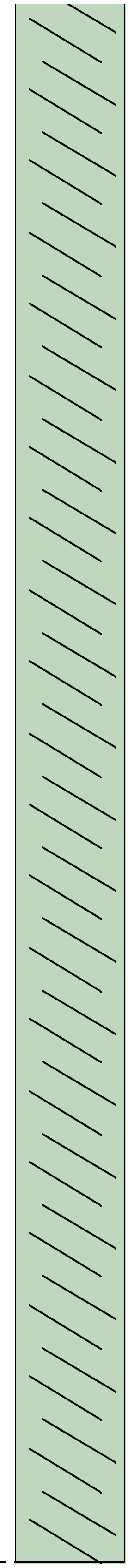
Survey: **HARS Coring 2002**
Core: **HU**
Total Core Length: **192 cm**

Longitude: -73.84945
Latitude: 40.36777
Cap Interface: 50 cm

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis		Lithology
						
	-100			99-101	Bulk Density, Water Content	
	-104					
	-108			109-111	Bulk Density, Water Content	
	-112					
	-116			119-121	Bulk Density, Water Content	
	-120					
	-124					
	-128					
	-132					
	-136					
	-140					
	-144					

The 2002 Survey of the 1993 Dioxin Mound

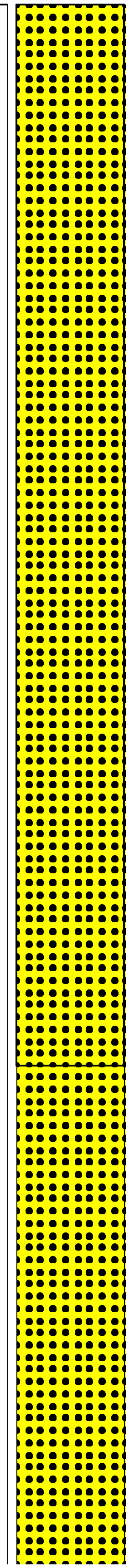
Survey: HARS Coring 2002
Core: HU
Total Core Length: 192 cm
Longitude: -73.84945
Latitude: 40.36777
Cap Interface: 50 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-148							
	-152			150-155	black clay with petroleum odor			
	-156							
	-160			160-170	black clay with petroleum odor			
	-164							
	-168							
	-172							
	-176			177-184	black clay with petroleum odor			
	-180							
	-184							
	-188							
	-192							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HV
Total Core Length: 238 cm

Longitude: -73.85057
Latitude: 40.36845
Cap Interface: 130 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	0, -4, -8, -12, -16, -20, -24, -28, -32, -36, -40, -44, -48, -52, -56, -60	0-42	brownish green to gray, no odor, moist, hard, SAND with Shell Fragments					
		42-98	mottled black and gray, no odor, moist, hard, SAND with Shell Fragments					

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002 **Longitude:** -73.85057

Core: HV **Latitude:** 40.36845

Total Core Length: 238 cm **Cap Interface:** 130 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-64, -68, -72, -76, -80, -84, -88, -92, -96							
						97-103	PCDD/PCDF, TOC	
		98-128	mottled black and dark gray, no odor, moist, hard, SAND with Shell Fragments			99-101	Bulk Density, Water Content	
	-100, -104, -108							
						109-111	Bulk Density, Water Content	
	-112, -116							
						117-123	Bulk Density, Grain Size - Sieve Only, PCDD/PCDF, TOC, Water Content	
	-120							

The 2002 Survey of the 1993 Dioxin Mound

Survey: HARS Coring 2002
Core: HV
Total Core Length: 238 cm

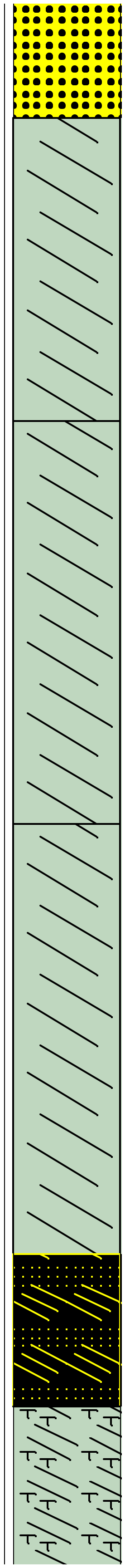
Longitude: -73.85057
Latitude: 40.36845
Cap Interface: 130 cm

Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology

Depth (cm): -124, -128, -132, -136, -140, -144, -148, -152, -156, -160, -164, -168, -172, -176, -180, -184

Major Interval	Description
128-140	black, organic/petroleum odor, moist, soft-firm, CLAY
140-156	mottled black and red, organic/petroleum odor, moist, soft-firm, CLAY
156-173	black, organic/petroleum odor, moist, soft-firm, CLAY
173-179	black with red bands, organic/petroleum odor, moist, firm, CLAY AND SAND
179-188	black, organic/petroleum odor, moist, soft-firm, SILTY CLAY

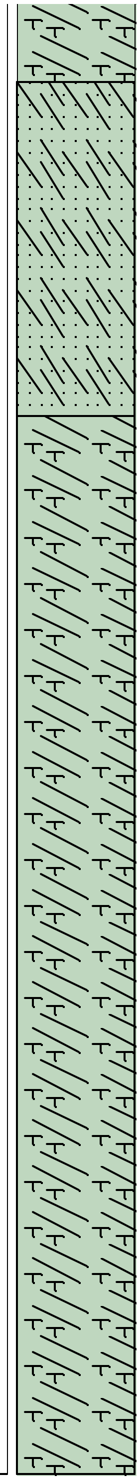
Analysis Interval	Analysis
137-143	PCDD/PCDF, TOC
139-141	Bulk Density, Water Content
149-151	Bulk Density, Water Content
157-163	Bulk Density, Grain Size - w/Hydrometer, PCDD/PCDF, Shear Strength, Specific Gravity, TOC, Water Content
169-171	Bulk Density, Water Content
179-181	Bulk Density, Water Content



The 2002 Survey of the 1993 Dioxin Mound

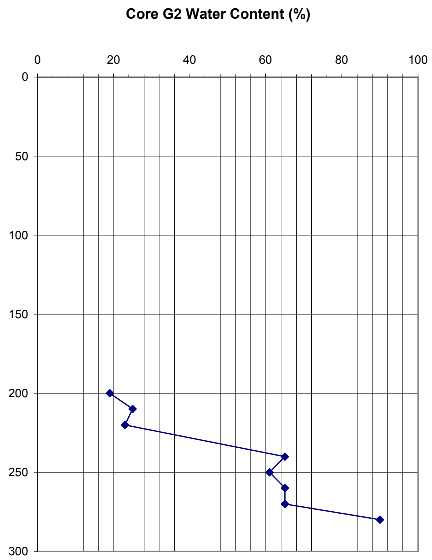
Survey: HARS Coring 2002
Core: HV
Total Core Length: 238 cm

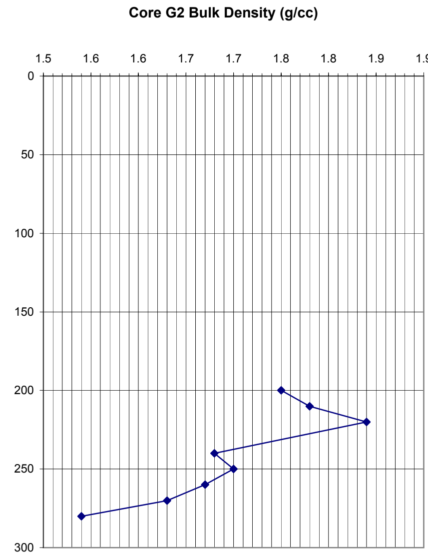
Longitude: -73.85057
Latitude: 40.36845
Cap Interface: 130 cm

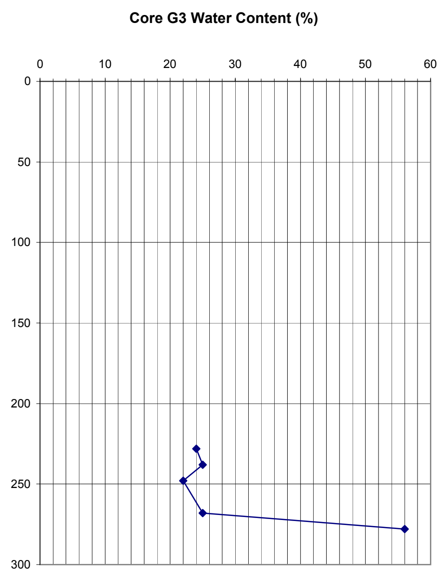
Core Photo	Depth (cm)	Major Interval		Sub-Interval		Analysis		Lithology
	-188 to -236	188-200	blackish brown, organic/petroleum odor, moist, soft-firm, SANDY CLAY			189-191	Bulk Density, Water Content	
		200-238	black, organic/petroleum odor, moist, soft-firm, SILTY CLAY			199-201	Bulk Density, Water Content	

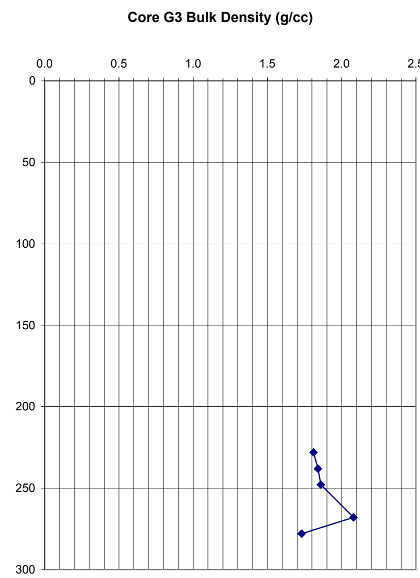
Depth scale: -188, -192, -196, -200, -204, -208, -212, -216, -220, -224, -228, -232, -236

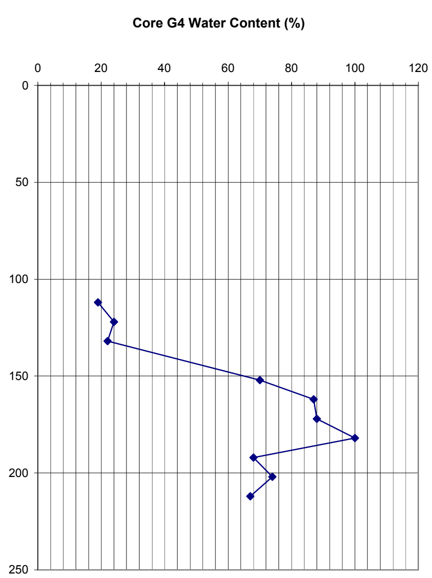
Appendix C-2
Plots of Water Content and Bulk Density with Depth in Each Core

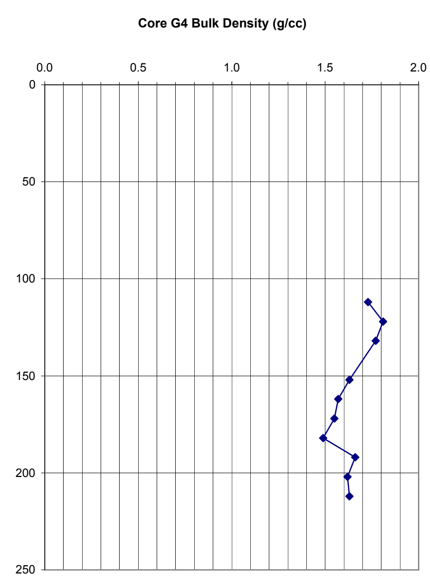

Core G2 Water Content (%)
0 20 40 60 80 100
0 50 100 150 200 250 300


Core G2 Bulk Density (g/cc)
1.5 1.6 1.6 1.7 1.7 1.8 1.8 1.9 1.9
0 50 100 150 200 250 300

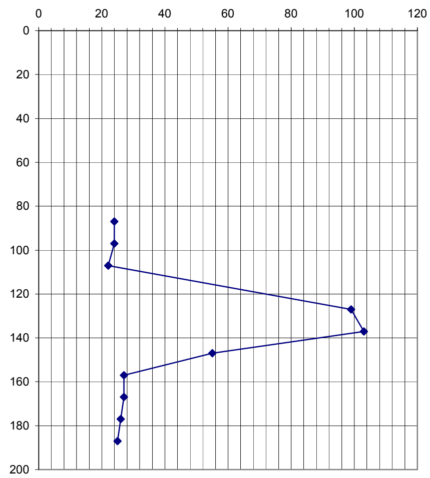

Core G3 Water Content (%)
0 10 20 30 40 50 60
0 50 100 150 200 250 300


Core G3 Bulk Density (g/cc)
0.0 0.5 1.0 1.5 2.0 2.5
0 50 100 150 200 250 300

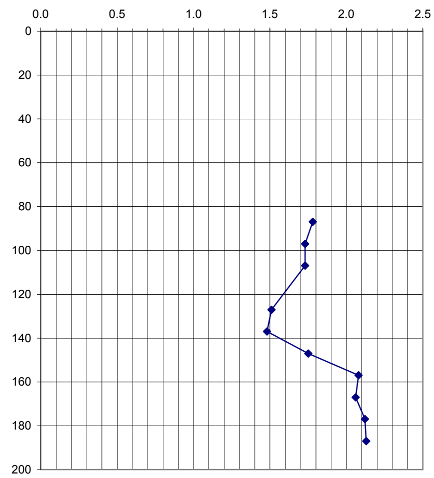

Core G4 Water Content (%)
0 20 40 60 80 100 120
0 50 100 150 200 250


Core G4 Bulk Density (g/cc)
0.0 0.5 1.0 1.5 2.0
0 50 100 150 200 250

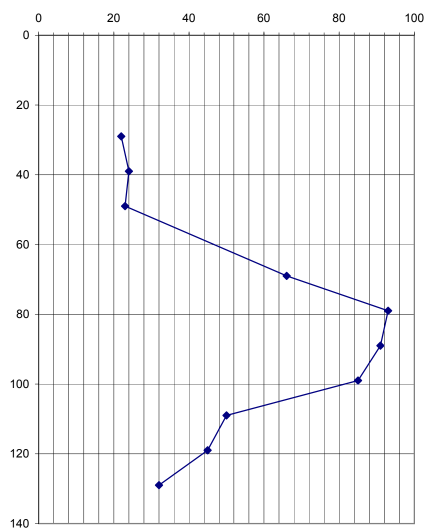
Core G5 Water Content (%)



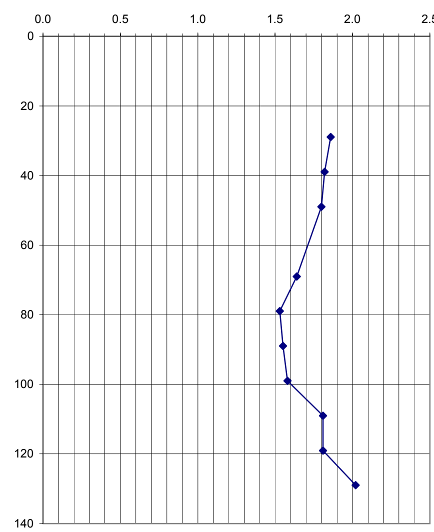
Core G5 Bulk Density (g/cc)



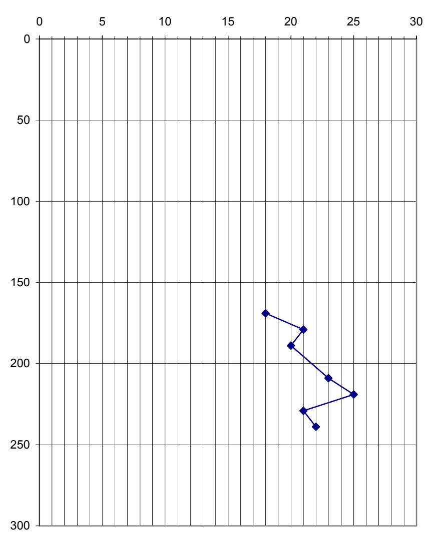
Core G6 Water Content (%)



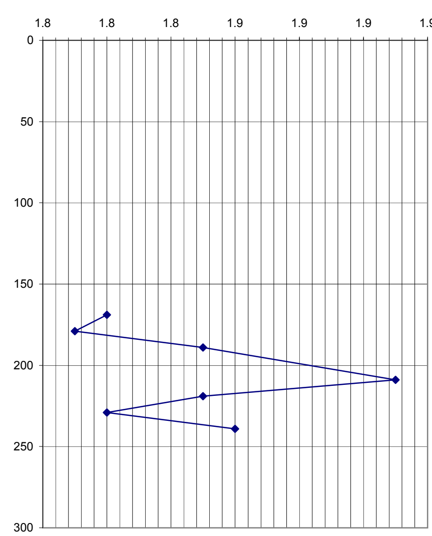
Core G6 Bulk Density (g/cc)



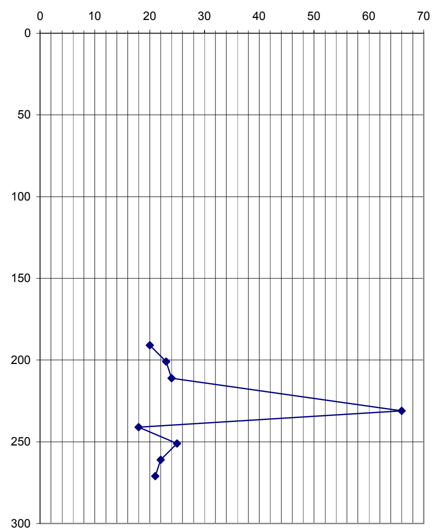
Core G7 Water Content (%)



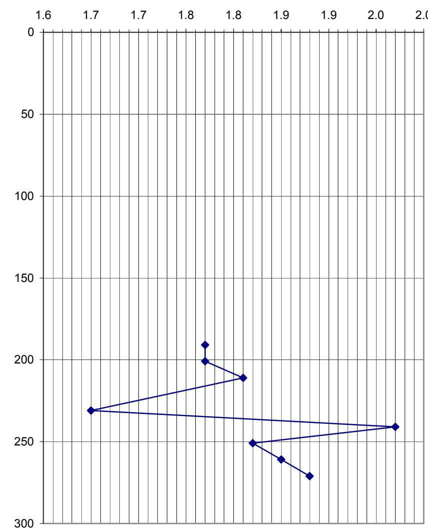
Core G7 Bulk Density (g/cc)



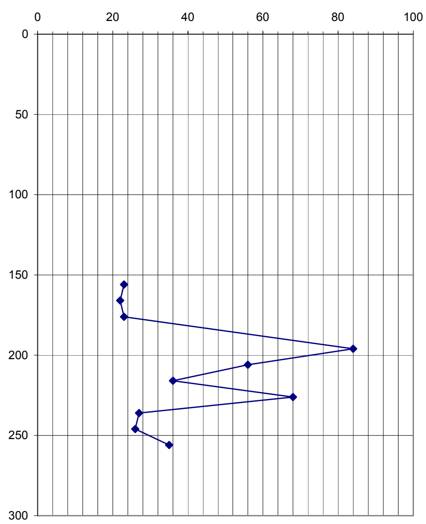
Core GX Water Content (%)



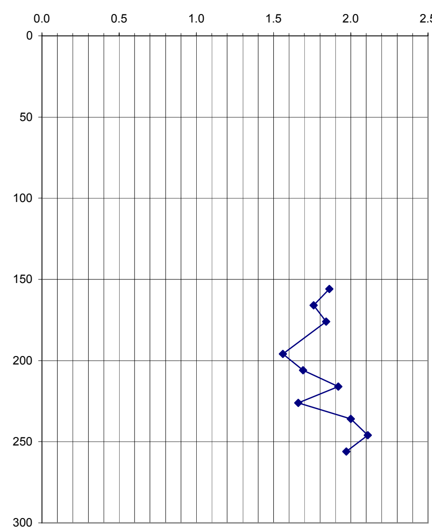
Core GX Bulk Density (g/cc)



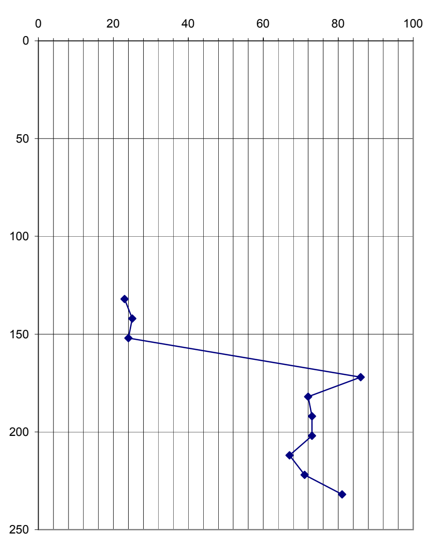
Core H2 Water Content (%)



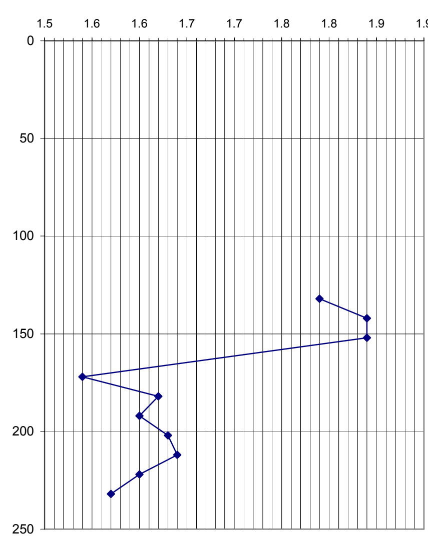
Core H2 Bulk Density (g/cc)



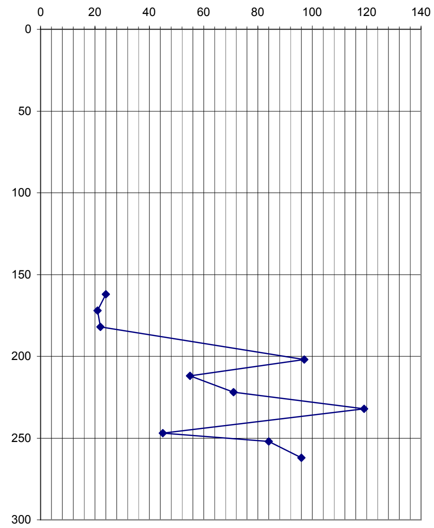
Core H3 Water Content (%)



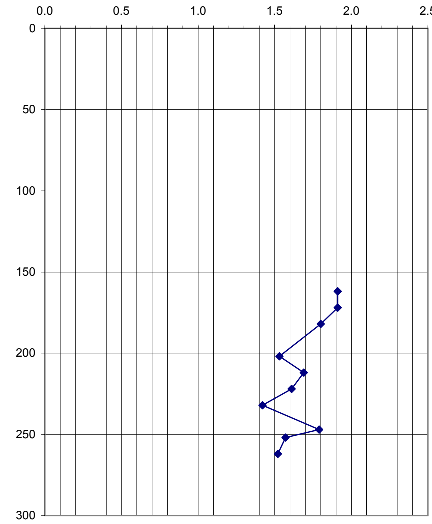
Core H3 Bulk Density (g/cc)



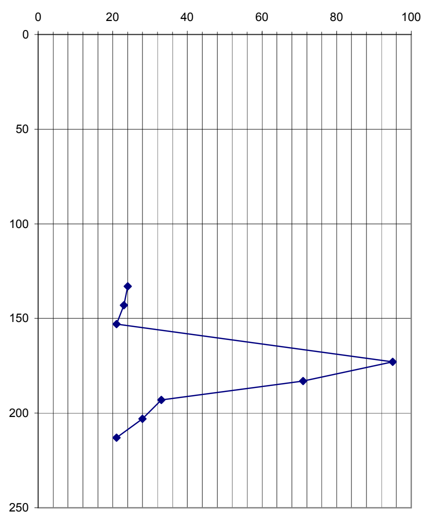
Core H4 Water Content (%)



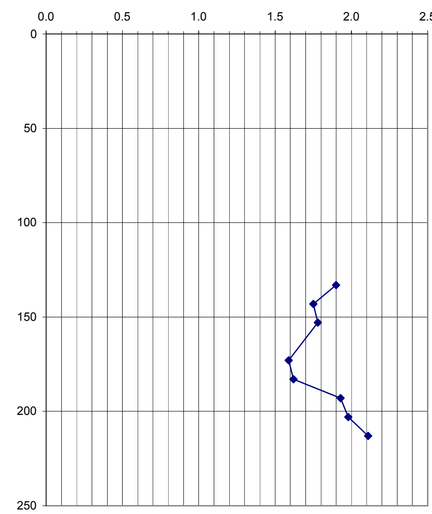
Core H4 Bulk Density (g/cc)



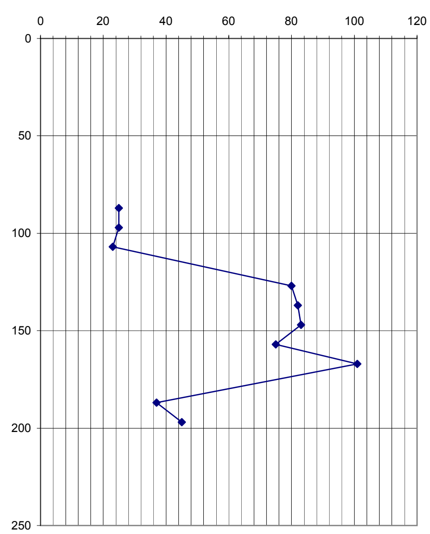
Core HS Water Content (%)



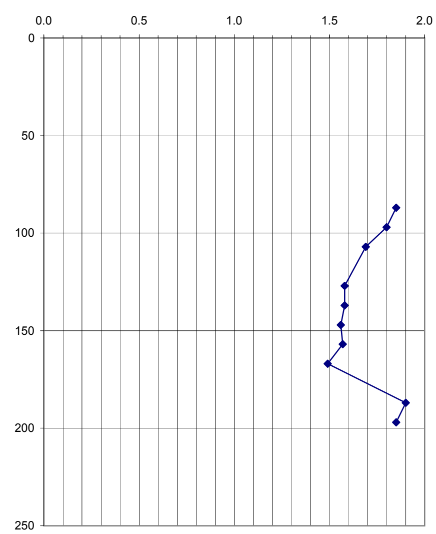
Core HS Bulk Density (g/cc)



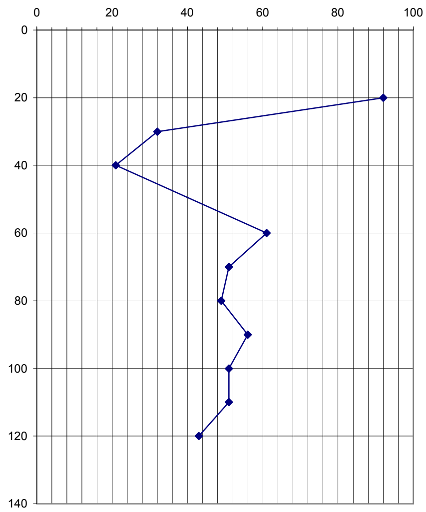
Core HT Water Content (%)



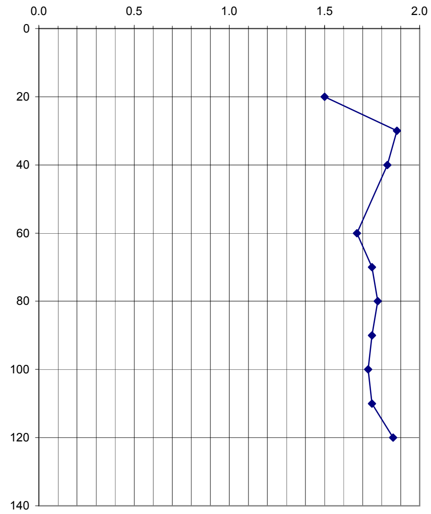
Core HT Bulk Density (g/cc)



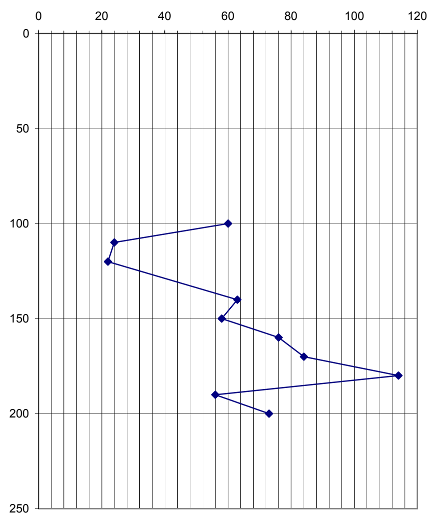
Core HU Water Content (%)



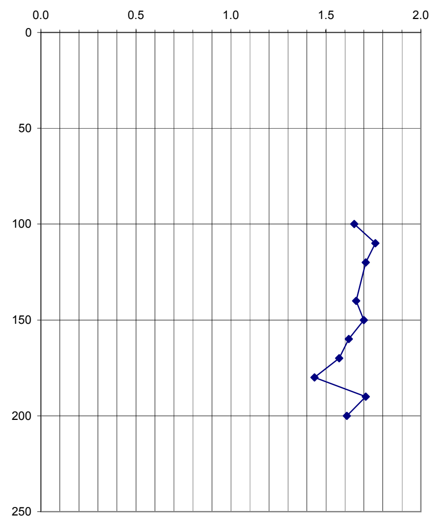
Core HU Bulk Density (g/cc)



Core HV Water Content (%)



Core HV Bulk Density (g/cc)



Appendix C-3

Water Content, Density, and Specific Gravity in Each Core Subsample

HARS 2002

Sediment Water Content and Density and Specific Gravity Results

SAIC Sample ID	W_c-Salt Corrected (%)	Wet Unit Wt. (g/cm^3)	Dry Unit Wt. (g/cm^3)	Specific Gravity
G2+200	19	1.75	1.48	-
G2+210	25	1.78	1.44	-
G2+220	23	1.84	1.51	-
G2-240	65	1.68	1.04	2.67
G2-250	61	1.70	1.08	-
G2-260	65	1.67	1.03	-
G2-270	65	1.63	1.01	-
G2-280	90	1.54	0.84	-
G3+228	24	1.81	1.48	-
G3+238	25	1.84	1.49	-
G3+248	22	1.86	1.53	-
G3-268	25	2.08	1.68	2.76
G3-278	56	1.73	1.13	-
G7+169	18	1.82	1.56	-
G7+179	21	1.81	1.50	-
G7+189	20	1.85	1.55	-
G7-209	23	1.91	1.56	2.69
G7-219	25	1.85	1.49	-
G7-229	21	1.82	1.52	-
G7-239	22	1.86	1.54	-
H3+132	23	1.79	1.46	-
H3+142	25	1.84	1.48	-
H3+152	24	1.84	1.49	-
H3-172	86	1.54	0.85	2.65
H3-182	72	1.62	0.97	-
H3-192	73	1.60	0.95	-
H3-202	73	1.63	0.97	-
H3-212	67	1.64	1.01	-
H3-222	71	1.60	0.96	-
H3-232	81	1.57	0.89	-
H4+162	24	1.91	1.55	-
H4+172	21	1.91	1.59	-
H4+182	22	1.80	1.48	-
H4-202	97	1.53	0.80	2.64
H4-212	55	1.69	1.11	-
H4-222	71	1.61	0.96	-
H4-232	119	1.42	0.68	-
H4-247	45	1.79	1.25	-
H4-252	84	1.57	0.88	-
H4-262	96	1.52	0.80	-
HS+133	24	1.90	1.55	-
HS+143	23	1.75	1.43	-
HS+153	21	1.78	1.48	-
HS-173	95	1.59	0.84	2.65
HS-183	71	1.62	0.97	-
HS-193	33	1.93	1.47	-
HS-203	28	1.98	1.56	-
HS-213	21	2.11	1.75	-

HARS 2002

Sediment Water Content and Density and Specific Gravity Results

SAIC Sample ID	W_c-Salt Corrected (%)	Wet Unit Wt. (g/cm^3)	Dry Unit Wt. (g/cm^3)	Specific Gravity
HT+87	25	1.85	1.50	-
HT+97	25	1.80	1.45	-
HT+107	23	1.69	1.38	-
HT-127	80	1.58	0.90	2.58
HT-137	82	1.58	0.89	-
HT-147	83	1.56	0.88	-
HT-157	75	1.57	0.92	-
HT-167	101	1.49	0.77	-
HT-187	37	1.90	1.41	-
HT-197	45	1.85	1.30	-
HU+20	92	1.50	0.81	-
HU+30	32	1.88	1.44	-
HU+40	21	1.83	1.53	-
HU-60	61	1.67	1.06	2.73
HU-70	51	1.75	1.18	-
HU-80	49	1.78	1.22	-
HU-90	56	1.75	1.14	-
HU-100	51	1.73	1.16	-
HU-110	51	1.75	1.18	-
HU-120	43	1.86	1.33	-
HV+100	60	1.65	1.05	-
HV+110	24	1.76	1.43	-
HV+120	22	1.71	1.41	-
HV-140	63	1.66	1.04	-
HV-150	58	1.70	1.10	-
HV-160	76	1.62	0.94	2.63
HV-170	84	1.57	0.88	-
HV-180	114	1.44	0.70	-
HV-190	56	1.71	1.11	-
HV-200	73	1.61	0.95	-
G4+112	19	1.73	1.46	-
G4+122	24	1.81	1.48	-
G4+132	22	1.77	1.46	-
G4-152	70	1.63	0.98	2.59
G4-162	87	1.57	0.87	-
G4-172	88	1.55	0.85	-
G4-182	100	1.49	0.77	-
G4-192	68	1.66	1.01	-
G4-202	74	1.62	0.96	-
G4-212	67	1.63	1.00	-
G5+87	24	1.78	1.45	-
G5+97	24	1.73	1.41	-
G5+107	22	1.73	1.43	-
G5-127	99	1.51	0.79	2.54
G5-137	103	1.48	0.76	-
G5-147	55	1.75	1.15	-
G5-157	27	2.08	1.65	-
G5-167	27	2.06	1.64	-
G5-177	26	2.12	1.70	-
G5-187	25	2.13	1.72	-

HARS 2002

Sediment Water Content and Density and Specific Gravity Results

SAIC Sample ID	W_c-Salt Corrected (%)	Wet Unit Wt. (g/cm^3)	Dry Unit Wt. (g/cm^3)	Specific Gravity
G6+29	22	1.86	1.54	-
G6+39	24	1.82	1.49	-
G6+49	23	1.80	1.48	-
G6-69	66	1.64	1.01	2.70
G6-79	93	1.53	0.82	-
G6-89	91	1.55	0.84	-
G6-99	85	1.58	0.88	-
G6-109	50	1.81	1.23	-
G6-119	45	1.81	1.27	-
G6-129	32	2.02	1.55	-
GX+191	20	1.77	1.49	-
GX+201	23	1.77	1.45	-
GX+211	24	1.81	1.47	-
GX-231	66	1.65	1.02	2.63
GX-241	18	1.97	1.69	-
GX-251	25	1.82	1.47	-
GX-261	22	1.85	1.53	-
GX-271	21	1.88	1.56	-
H2+156	23	1.86	1.53	-
H2+166	22	1.76	1.46	-
H2+176	23	1.84	1.50	-
H2-196	84	1.56	0.87	2.59
H2-206	56	1.69	1.10	-
H2-216	36	1.92	1.43	-
H2-226	68	1.66	1.01	-
H2-236	27	2.00	1.59	-
H2-246	26	2.11	1.69	-
H2-256	35	1.97	1.48	-
SA2-20	32	1.93	1.48	-
SA2-80	141	1.39	0.61	-
SA2-120	107	1.47	0.74	2.58
SA2-200	31	1.90	1.47	-
SA2-240	52	1.75	1.17	-
RC68-10	76	1.61	0.94	-
RC68-40	46	1.78	1.24	2.77
RC68-70	39	1.87	1.36	-
RC68-100	39	1.86	1.36	2.78
RC68-140	38	1.86	1.36	-
RC76-30	25	2.03	1.64	-
RC76-60	40	1.84	1.33	-
RC76-90	43	1.84	1.31	-
RC76-150	36	1.89	1.40	2.75
RC76-220	24	2.17	1.76	-

Appendix C-4

Sediment Grain Size Results for Each Core Subsample

HARS 2002 Coring

Sediment Grain Size Summary Table

CAP MATERIAL

Sample ID	Gravel >#4 (%)	Coarse Sand #10 (%)	Medium Sand #20-#40 (%)	Fine Sand #60-#200 (%)	Silt 0.074-0.005 mm (%)	Clay <0.005 mm (%)	Passing No. 200 <0.074 mm (%)	USCS Classification
G2+220	0.00	1.68	17.21	80.57	-	-	0.53	SP
G3+248	2.94	1.91	14.02	80.76	-	-	0.38	SP
G7+189	1.54	4.27	23.42	70.51	-	-	0.27	SP
G4+132	1.00	0.99	13.11	84.67	-	-	0.23	SP
G5+107	1.75	0.61	11.20	86.17	-	-	0.27	SP
G6+49	1.69	1.43	10.73	85.84	-	-	0.30	SP
GX+211	0.77	0.77	9.02	89.06	-	-	0.38	SP
GX+211 (dup)	0.87	0.63	10.41	87.75	-	-	0.34	SP
H2+176	0.00	0.78	14.71	84.13	-	-	0.37	SP
H3+152	1.08	0.71	8.02	89.79	-	-	0.40	SP
H4+182	0.34	1.08	13.72	84.60	-	-	0.26	SP
H4+182 (dup)	0.36	1.04	13.77	84.51	-	-	0.32	SP
H4+182 (tri)	0.35	0.98	13.75	84.65	-	-	0.27	SP
HS+153	0.94	1.67	16.34	80.84	-	-	0.21	SP
HT+107	0.43	1.11	9.18	88.95	-	-	0.32	SP
HU+40	0.10	0.15	18.02	81.35	-	-	0.37	SP
HV+120	0.93	1.07	11.31	86.45	-	-	0.24	SP

DREDGED MATERIAL

Sample ID	Gravel >#4 (%)	Coarse Sand #10 (%)	Medium Sand #20-#40 (%)	Fine Sand #60-#200 (%)	Silt 0.074-0.005 mm (%)	Clay <0.005 mm (%)	Passing No. 200 <0.074 mm (%)	USCS Classification
G2-240	0.00	0.00	0.47	8.48	53.06	38.00	-	ML
G3-268	27.97	6.62	10.46	10.08	16.87	28.00	-	GC
G7-209	0.43	0.29	11.79	80.74	2.66	4.10	-	SP-SC
G4-152	0.00	0.00	0.93	14.16	39.41	45.50	-	CH
G5-127	0.00	0.47	0.72	5.08	34.23	59.50	-	CH
G6-69	1.60	1.91	2.43	5.10	29.96	59.00	-	CH
GX-231	0.00	1.23	19.25	29.26	20.26	30.00	-	CL
GX-231 (dup)	0.00	1.11	18.45	31.42	18.52	30.50	-	CL
H2-196	0.00	0.00	0.29	6.64	38.07	55.00	-	CH
H3-172	0.00	0.09	0.28	1.79	34.84	63.00	-	CH
H3-172 (dup)	0.00	0.10	0.28	1.89	35.24	62.50	-	CH
H3-172 (trip)	0.00	0.08	0.27	1.66	37.48	60.50	-	CH
H4-202	0.00	0.00	0.14	3.57	41.29	55.00	-	CH
HS-173	0.00	0.00	0.33	4.25	36.92	58.50	-	CH
HT-127	0.00	0.29	1.94	9.39	36.87	51.50	-	CH
HU-60	2.00	0.36	2.40	9.73	22.51	63.00	-	CH
HV-160	0.00	0.29	2.22	7.71	39.78	50.00	-	CH

Appendix C-5

Core Shear Strength Results

Appendix C-5
2002 Summary of Shear Strength Results for The 1993 Dioxin Mound

Core Station	Inner Degree of Rotation	Outer Degree of Rotation	Torque (Nm)	Shear Strength (kN/m^2)
H2	47	18	0.19	25.36
H3	115	23	0.47	62.06
H4	79	24	0.32	42.63
HS	31	26	0.13	16.73
HT	81	24	0.33	43.71
HU	42	24	0.17	22.66
HV	39.5	14	0.16	21.32
G2	75	25	0.30	40.47
G3	69	20	0.28	37.24
G4	92	25	0.37	49.65
G5	47	24	0.19	25.36
G6	24	14	0.10	12.95
G7*	NA	NA	NA	NA
GX	49	28	0.20	26.44

* Core G7 contained all sand, preventing analysis for shear strength

Appendix C-6

Dioxin and Furan Concentrations in Each Core Subsample

Appendix C-6

CAP MATERIAL																	
Compound Name	**G2+200**	**G2+220**	**G3+228**	**G3+248**	**HV+100**	**HV+120**	**HT+87**	**HT+107**	**H4+182**	**H4+162**	**H3+132**	**H3+152**	**Average**	**Stdev.**	**Minimum**	**Maximum**	**Sample Count**
2,3,7,8-TCDF (Furan)	0.14	0.1	0.095	0.095	0.095	0.1	0.1	0.2	0.095	0.11	0.1	0.21	0.12	0.04	0.095	0.21	12
2,3,7,8-TCDD (Dioxin)	0.19	0.1	0.095	0.095	0.12	0.11	0.13	0.145	0.095	0.13	0.1	0.3	0.13	0.06	0.095	0.3	12
1,2,3,7,8-PeCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	24	2.45	6.79	0.48	24	12
2,3,4,7,8-PeCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	5	0.87	1.30	0.48	5	12
1,2,3,7,8-PeCDD	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	2	0.62	0.44	0.48	2	12
1,2,3,4,7,8-HxCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	18	1.95	5.05	0.48	18	12
1,2,3,6,7,8-HxCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	3.15	0.71	0.77	0.48	3.15	12
2,3,4,6,7,8-HxCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	2.15	0.63	0.48	0.48	2.15	12
1,2,3,7,8,9-HxCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	1	0.53	0.15	0.48	1	12
1,2,3,4,7,8-HxCDD	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	1.5	0.57	0.29	0.48	1.5	12
1,2,3,6,7,8-HxCDD	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	6.5	0.99	1.74	0.48	6.5	12
1,2,3,7,8,9-HxCDD	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	3.25	0.72	0.80	0.48	3.25	12
1,2,3,4,6,7,8-HpCDF	0.49	0.495	0.48	1.1	0.485	0.495	0.495	1.6	0.485	1.9	0.5	1.1	0.80	0.50	0.48	1.9	12
1,2,3,4,7,8,9-HpCDF	0.49	0.495	0.48	0.485	0.485	0.495	0.495	0.48	0.485	0.495	0.5	0.48	0.49	0.01	0.48	0.5	12
1,2,3,4,6,7,8-HpCDD	0.49	0.495	1	4.3	1.2	1.4	2.1	3.2	1.8	7.1	1.1	2.4	2.22	1.90	0.49	7.1	12
OCDF	1	1	0.95	7.1	0.95	1	1	2.7	0.95	7.5	1	2.2	2.28	2.42	0.95	7.5	12
OCDD	11	6.4	13	46	14	18	18	32	20	66	15	25	23.70	17.00	6.4	66	12
TEC	0.011	0.0064	0.023	0.11	0.026	0.032	0.039	0.083	0.039	0.16	0.026	0.38	0.08	0.11	0.01	0.38	12

DREDGED MATERIAL																	
Compound Name	**G2-240**	**G2-260**	**G3-268**	**G3-278**	**HV-140**	**HV-160**	**HT-127**	**HT-147**	**H4-202**	**H4-222**	**H3-192**	**H3-172**	**Average**	**Stdev.**	**Minimum**	**Maximum**	**Sample Count**
2,3,7,8-TCDF (Furan)	0.68	0.38	7.6	4.9	3.5	5.7	32	23	22	3.7	6.2	6.2	9.66	10.16	0.38	32	12
2,3,7,8-TCDD (Dioxin)	1	1.1	39	20	27	27	89	73	100	10	70	31	40.68	34.03	1	100	12
1,2,3,7,8-PeCDF	2.5	4.8	190	3.4	150	12	23	37	21	6	23	48	43.39	61.35	2.5	190	12
2,3,4,7,8-PeCDF	0.47	0.465	13	4.5	6.4	8.8	39	24	26	4.4	7.8	10	12.07	11.73	0.465	39	12
1,2,3,7,8-PeCDD	0.47	0.465	3.3	2.8	2.4	3.4	11	9	9.1	2.1	4.5	4	4.38	3.46	0.465	11	12
1,2,3,4,7,8-HxCDF	0.47	1.3	37	9.3	12	31	200	40	72	10	20	36	39.09	54.61	0.47	200	12
1,2,3,6,7,8-HxCDF	0.47	0.465	7.5	5.2	8.4	6.7	42	16	23	2.9	5.9	6.3	10.40	11.80	0.465	42	12
2,3,4,6,7,8-HxCDF	0.47	0.465	7.1	5.1	3.6	3.9	20	13	15	3.5	5.7	4.3	6.84	6.03	0.465	20	12
1,2,3,7,8,9-HxCDF	0.47	0.465	3.3	1.6	1.6	1.7	10	6.1	6.6	1.3	2.9	2	3.17	2.92	0.465	10	12
1,2,3,4,7,8-HxCDD	0.47	0.465	4.7	1.8	2.3	2.6	8.7	6.8	5.9	1.4	3.5	3	3.47	2.58	0.465	8.7	12
1,2,3,6,7,8-HxCDD	0.47	0.465	15	8	11	11	52	32	40	6.9	11	13	16.74	16.06	0.465	52	12
1,2,3,7,8,9-HxCDD	0.47	0.465	7.5	4.2	4.3	5.1	16	15	16	3.4	5.5	6.5	7.04	5.61	0.465	16	12
1,2,3,4,6,7,8-HpCDF	4.4	4.4	130	79	81	99	820	290	360	38	91	110	175.57	229.15	4.4	820	12
1,2,3,4,7,8,9-HpCDF	0.47	0.465	7.9	3.8	4.6	5	31	11	13	3.3	5.3	6.3	7.68	8.23	0.465	31	12
1,2,3,4,6,7,8-HpCDD	17	11	200	170	160	160	1200	430	500	89	170	220	277.25	324.49	11	1200	12
OCDF	5.9	9.7	240	140	150	180	1500	460	580	89	170	220	312.05	409.76	5.9	1500	12
OCDD	590	220	1800	1500	1500	1500	9900	4300	4900	930	1400	2000	2545.00	2696.75	220	9900	12
TEC	1.8	1.6	60	30	39	35	180	110	150	15	84	41	62.28	57.73	1.6	180	12